Lecture Notes in Management and Industrial Engineering

Elisabeth Viles
Marta Ormazábal
Alvaro Lleó *Editors*

Closing the Gap Between Practice and Research in Industrial Engineering

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Preface

It is an honor to present a selection of papers that were accepted at the CIO-ICIEOM-IIE-AIM 2016, called International Joint Conference (IJC2016): “XX Congreso de Ingeniería de Organización,” “XXII International Conference on Industrial Engineering and Operations Management,” “International IISE Conference 2016,” and “International AIM Conference 2016.”

This Joint Conference is a result of an agreement among ADINGOR (Asociación para el desarrollo de la Ingeniería de Organización), ABEPRO (Associaçâo Brasileira de Engenharia de Produçâo), IISE (Institute of Industrial & Systems Engineers), and AIM (European Academy for Industrial Management). The conference has been organized by the Industrial Management Department at Tecnun (School of Engineering—University of Navarra).

The International Joint Conference (IJC2016)’s motto is “Building bridges between researchers and practitioners.” The mission of the conference is to promote links between researchers and practitioners from different areas of industrial engineering and management, in order to enhance an interdisciplinary perspective of the field. The contributions of this book have been organized in nine parts:

– Strategy and Enterpreneurship
– Operations Research, Modeling, and Simulation
– Logistics
– Production
– Quality and Product Management
– Knowledge and Project Management
– Service Systems
– Industry 4.0
– Education

We want to thank the Institutional Supporters and Sponsors. We gratefully acknowledge to the Invited Speakers, Authors, and Reviewers. We must also recognize the great effort of the Scientific and Organizing Committees.

San Sebastián, Spain
August 2016

Elisabeth Viles
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Part I
Strategy and Entrepreneurship

Innovative Spillovers and Efficiency in the Brazilian Industry

B.D. Yamashita, H.F. Moralles, N.B. Santana and D.A.N. Rebelatto

Abstract Given that a fraction of the output is not explained by variations in traditional inputs, public innovative spillovers effects may represent important implications on industrial efficiency. This study aims to identify the factors and characteristics that determine the technical efficiency of the Brazilian industry, using the DEA and logistic regression model. The results pointed that investments in non-traditional inputs are efficiency drivers. Regarding to public investments and technological intensity, no innovative spillover effects were found to contribute to technical efficiency for the analyzed Brazilian industries.

Keywords Efficiency · Spillovers · Innovation · DEA · Logistic regression

1 Introduction

Since Griliches (1979), it has been known that a fraction of the output is not explained by variations in traditional inputs, with investment in R&D recognized in the literature as an important non-traditional input. Its social return has considerable

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impact, once accumulation of R&D represents an important engine of economic growth.

Non-traditional inputs, such as R&D, management and training, define much of the efficiency and competitiveness of companies, as they directly affect the technological relationship and the ability to transform inputs into outputs described by the production function.

The reduced product life cycle seen in the last decade emphasizes the need to reduce costs and improve efficiency, which means increasing the importance of R&D departments (Kafouros 2006). Thus, since R&D helps leverages the company's revenue structure by creating or improving products and processes, R&D expenditures should not be disregarded, as well as their influence on improving production processes.

Based on that, governments encourage the collaboration between academic scientists and private companies to have social and economic benefits and associated spillovers, even if the dynamics of innovation investment does not guarantee such effects (Benjamin 2011).

According to Gittelman (2006), new ideas are absorbed and applied faster by companies with specific conditions, which could be, for instance, belonging to the science sector, such as biotechnology and capital goods.

Understanding externalities (spillovers) of knowledge and technology is crucial to understand innovation mechanisms and economic growth dynamics. In this context, models are developed to explain the knowledge diffusion methods between companies (Autant-Bernard and LeSage 2011).

Eng and Ozdemir (2014) also address such dynamics in a study about integration of R&D departments between companies, and it found out the performance of new product development increases with higher degree of integration of R&D departments. Such integration is favored in environments of high uncertainty. Then, intercommunication between economic entities driven by IT and globalization result in spillovers with important implications and productivity (Tsai and Lin 2005).

Based on this scenario, this study aims to identify the factors and characteristics that determine the efficiency of the Brazilian industry in technical terms, using the DEA model and logistic regression. Such factors were selected according to the literature available, which are: non-traditional inputs (management, training, and R&D), public innovation and technological intensity.

2 Foundations and Research Hypotheses

Considering that governments want to promote socio-economic outputs resulting from technological innovation and competitive advantages of investments in S&T activities, this study aims to identify the factors and characteristics that determine the Brazilian industry efficiency in technical terms. This purpose has led to the formulation of three hypotheses.

Hypothesis 1: Companies with high expenditures in non-traditional inputs such as R&D and management (according to the "differed" account) have higher probability to be efficient.

Hypothesis 2: The public innovative investment has contributed to technical efficiency of Brazilian industries.

Hypothesis 3: Technology-intensive companies have higher probability to be efficient.

3 Methods

Data from Brazilian enterprises were collected from 2000 to 2010. Specifically, companies' data were collected from their consolidated balance sheet available on the BOVESPA website. Then, a Cobb-Douglas based model was employed, and the following proxies were applied: gross revenue of sales as the product, total fixed assets as the capital and salary expenditures as labor. Here, the data were deflated using Brazil's general price index (IGP-DI) to deal with the inflationary effects. Additionally, the capital variable has a 10% depreciation rate per year.

To model the enterprise R&D and other nontraditional inputs, an account of the Brazilian financial statements called "differed" was used as proxy, which mainly records expenditures on R&D, management and employee training.

The public innovation investment variable was comprised of state and federal expenditures on R&D activities from 1998 to 2010. The federal expenditures were collected at the integrated system of financial administration of the Brazilian federal government (SIAFI), and the State expenditures are available at the Brazilian Ministry of Science and Technology (MCT).

The calculation of companies' efficiency was performed by means of the data envelopment analysis (DEA) model. Besides, considering collected data are longitudinal, a window analysis was applied in order to calculate the relative efficiency.

3.1 Application of DEA and Logistic Regression

The proposed DEA technique uses two input variables (total fixed assets and salary expenditures) and one output variable (gross revenue of sales). After applying the criterion proposed by Nunamaker (1985), which defines that the number of units analyzed in the DEA should be at least three times the sum of inputs and outputs, then the number of analyzed units should be at least nine.

In this study, the BCC model proposed by Banker et al. (1984) for variable returns of scale was selected because the transformation of materials into goods cannot be described as a linear process. The BCC model selection indicates outputs increase or decrease in a different proportion when compared to inputs, respecting the question of size of the analyzed units. It means reductions or increments in inputs do not generate alterations in the same proportion in outputs.

The DEA was processed using Frontier Analyst Professional software. In this study, every company in time (from 2000 to 2010) was considered a distinct unit. According to Cooper et al. (2000), a time-dependent version of DEA is known as ‘window analysis’, a technique that considers the time unit as a distinct unit.

The window analysis is a similar process to a moving average, where every time a new time unit comes in, another one goes out, usually the first that came in the analysis before. Cooper et al. (2000) used the relations of (1) to calculate the number of windows and window amplitude.

$$W = k - p + 1, \quad \text{with} \quad p = (k + 1)/2 \tag{1}$$

where: W = number of windows; k = number of year; and p = window amplitude.

In this study, the period analyzed was 10 years (k = 10). Then, the calculations established the number of windows for DEA would be six and window amplitude would be five.

Lastly, to test the study hypotheses about determinants of efficiency, a panel data logistic regression was conducted, replacing years with the six windows estimated in DEA, according to the model of (2).

$$Ef_{it} = \gamma_1 N_{it} + \gamma_2 P_{it} + \gamma_3 T_{it} + \varepsilon_{it} \tag{2}$$

where,

Ef_{it} = for efficient company; or zero for inefficient company;
N_{it} = Stock of non-traditional inputs;
P_{it} = Stock of public S&T;
T_{it} = 1 if the company has a high technological activity; otherwise, zero.

Here, the variables of non-traditional inputs and public investment in S&T activities are represented in terms of stock, considering the activities like R&D tend to be computed in the literature. Then, the variables of Eq. (2) are described as in (3) and (4), for every unit n until time h.

$$N_{it} = \sum_{h=1}^{n} (N_{it}^{h}), k \quad \text{with} \quad h = 1 \ldots t \tag{3}$$

$$P_{it} = \sum_{h=1}^{n} (P_{it}^{h}), \quad \text{with} \quad h = 1 \ldots t \tag{4}$$

The technological intensity variable was defined using the classification of OECD (2005) through sector, and the panel model was estimated through maximum likelihood, with non-binary variables in terms of logarithms to reduce any potential heteroscedasticity, and the possibility of serial correlation through an AR (1) structure in residuals. Lastly, the marginal effects of the mean values were used in result interpretation.

4 Results

The DEA window model was applied using the window analysis to accommodate the panel, whose ranking of efficient companies is presented in Table 1.

To define the binary variable (dependent), the mean of efficiency scores was used. According to Table 1, the mean of efficiency was 41.46% and this value was adopted as the cutoff score for the definition of the proportion of companies that would be classified as efficient and inefficient. For example, company 16 represented the cutoff point, that is, 40% of the companies presented score 1 (efficient) and 60% score zero (inefficient).

Table 2 shows the marginal effects related to mean elasticity, estimating logistic regression through random effects (RE) and demean (PA); the latter allowing the

Table 1 Efficiency score after DEA application with window analysis

Unit	W1	W2	W3	W4	W5	W6	Window mean
DMU1 (%)	100.0	100.0	100.0	100.0	99.4	98.3	99.6
DMU2 (%)	94.9	98.2	95.3	95.6	95.2	89.6	94.8
DMU3 (%)	73.1	87.3	93.0	97.8	93.6	93.6	89.7
DMU4 (%)	88.8	89.4	90.4	85.0	81.3	77.9	85.5
…							
DMU35 (%)	18.3	18.5	17.9	17.2	13.0	11.6	16.1
DMU36 (%)	16.3	16.4	15.6	16.5	14.5	13.9	15.5
DMU37 (%)	13.3	13.7	14.2	13.8	13.6	14.7	13.9
DMU38 (%)	10.2	9.5	10.7	11.7	12.0	14.3	11.4
DMU39 (%)	13.8	12.7	11.1	10.8	8.7	8.4	10.9
DMU40 (%)	9.9	10.4	10.3	9.3	8.4	5.9	9.1
Mean (%)	41.3	43.0	43.4	43.4	41.6	40.5	41.4

Table 2 Marginal effects

Variable	Marginal effect at mean			
	RE		PA (AR1)	
	Coefficient	p value	Coefficient	p value
In Stock non-traditional inputs (Differed)	0.132	0.004	0.008	0.011
In Stock public S&T	−0.243	0.229	−0.012	0.424
In technological intensity	−3.768	0.249	−0.152	0.294

incorporation of an autoregressive structure AR(1) to residuals to accommodate possible serial correlation.

Therefore, based on the results, only non-traditional input variable was significant, indicating that only Hypothesis 1 was confirmed. In other words, based on the estimation results through PA, a 1% increment in private investments in non-traditional inputs (R&D and management, for example) increases by 0.8%, on average, the probability of a company to be efficient. Such results agree with the studies conducted by Eng and Ozdemir (2014), Liik et al. (2014).

The results presented in Table 2 indicate Hypothesis 2 about public innovative investment and its effects on the efficiency of Brazilian industries was rejected, based on its p-value of 0.424. It indicates the spillover effects associated with public S&T activities have not determined the technical efficiency of Brazilian industries analyzed in this study.

The same happened with technological intensity (Hypothesis 3), whose result was also negative (p-value = 0.294), indicating technological intensity is not a determinant of technical efficiency. This result does not agree with those found in other countries, as reported in the studies conducted by Liik et al. (2014), Moralles and Rebelatto (2015) and O'Mahony and Vecchi (2009).

5 Conclusions

This study aimed to analyze the determinants of technical efficiency in Brazilian industries, considering the expenditures in non-traditional inputs like management and R&D, public investments on S&T activities, which would indicate the existence of spillover effects and, the technological intensity characteristic.

The model pointed that only Hypothesis 1 showed positive results, which indicates investments in non-traditional inputs are efficiency drivers. Regarding public investments, no innovative spillover effects contributed to technical efficiency of Brazilian industries analyzed in this study.

Lastly, this study also observed that, in the Brazilian scenario, the technological intensity is not a determinant of efficiency. It is probably due to the fact that Brazilian technology-intensive companies import a large part of knowledge related to their activities from developed countries. Then, the adaptation of certain technologies may cause inconsistencies and technical problems that affect the efficiency of such organizations.

Future studies could investigate such causes by comparing Brazil directly to other realities in terms of technological intensity, as well as the effect of public policies and the causes of inexistent innovative spillover effects.

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Supply Chain Sustainability in Spanish Major Retailer Through Strategic Alliances and Lean Practices

Jesús Morcillo-Bellido and Alfonso Duran

Abstract Sustainability within the supply chain is an issue that appeared and has been widely studied in the last decade of the twentieth century, but it is only now reaching the maximum level of interest among academics and business executives. In this paper, authors analyze if some specific practices linked to lean operations, superior alliances management integration and people involvement are really supporting sustainability in the largest and most successful Spanish retailer. It was a standard retailer for years, till it changed its company strategy, from price-based competition (based on squeezing suppliers and low wages) to integral supply chain waste reduction and quality improvement, "for life" alliances with its main top suppliers and labor relations based on permanent contracts, polyvalence and employee motivation. Another important aim of this study is to understand to what extend the alliances developed with its top suppliers, have incorporated and replicated the practices developed by this Spanish retailer, thus creating an excellence/amplification mechanism that supports long-term supply chain sustainability.

Keywords Sustainability · Supply chain · Strategic alliances · Lean operations

1 Introduction

Sustainability, in the sense of integrating aspects related to the economic, social and environmental impact into business management, started to appear in the literature during last decade of the twentieth century (Carter and Rogers 2008), largely reflecting the sustainability vision developed by the Brundtland

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Commission (WCED 1987). These aspects were integrated into a global concept that has been named in the literature "the triple bottom line," developed by Elkington (1998, 2004), corresponding to the idea of always having in mind the three outcomes (and impact) in the management of any twenty-first century's company. Therefore, only organizations which achieve the right balance in the management of their activities that will lead to economic, social and environmental acceptable results could be considered as a "sustainable organization".

Forrester (1958) introduced a theory of distribution management that recognized the nature of organizational relationships. Some years later authors such as Cooper et al. (1997) have coined the term "supply chain", meaning a set of firms that jointly provide goods to the end customer; these organizations are involved in sourcing, manufacturing, and delivering goods and services to the final user and generating adding value, being all members of a supply chain (Christopher 1992; la Londe and Masters 1994; Lambert et al. 1998). Within this supply chain vision, it is essential not only to integrate management practices that promote the achievement of "traditional" chain objectives, such as cost, service quality and reliability, but must go beyond them and having additionally focus on related social and environmental issues (Carter and Rogers 2008; Alzaman 2014).

McKinsey (2012) published a study of more than three thousand online interviews with worldwide business executives, and in this study conclude that the three main issues on which companies are taking action to achieve more sustainable business practices in the supply chain are: (i) reduction in energy consumption (66%), (ii) reduction of waste (64%), and (iii) corporate social responsibility (57%). The second aspect is closely related to practices that have been called "lean operations", within the concept of "lean" developed by Womack and Jones (2010) and which generated a lot of interest by emphasizing organization's waste elimination as a step beyond the so call "lean manufacturing" (Womack et al. 1990), which is considered as an extension of the concepts and practices developed under the Toyota Manufacturing System (Ohno 1988). Authors like Govindan et al. (2014) consider aspects of "lean" and "resilience" [ability to recover when an unexpected event happens (Sheffi 2005)] are critical to enable companies to become more sustainable, in a holistic manner, in today's highly volatile markets.

Authors of this study consider that some organizations have implemented a combination of the above mentioned aspects with their particularities, as part of its business strategy to move further in building sustainable supply chains. The supply chain built by Spanish retail distribution leader Mercadona and its more than one hundred "inter-providers" could be an example of sustainable supply chain that goes way beyond what is usually described. In a previous study, Morcillo and Duran (2015) have described how the collaborative relationships (alliances) between Mercadona and its inter-providers, supported by factors such as "common strategic shares objectives" and "long-term commitment", generated added value for alliance performance that explained Mercadona's greater success ratio in partnerships with its inter-providers. According to the authors of this study, these two qualitative factors provide a special "added value" in the partner's relationship. In the current study, authors want to take one additional step, by checking if this supply chain really exhibits traits that would qualify it as "sustainable". They explore if Mercadona's supply chain sustainability could be explained by the building of a "harmonious whole" of factors that distinguish it from other supply chains: (i) factors that explain the formation of alliances, which also occur in other companies (ii) additional alliance factors that strengthen its partnerships (long term commitment and common objectives) (Morcillo and Duran 2015), (iii) the use of "lean operations" practices, both in Mercadona and its inter-providers, and particularly, (iv) the replication of the model developed by Mercadona in its main inter-providers.

2 Objective and Study Methodology

The main objective is to study to what extent Mercadona and its main suppliers have developed mechanisms that promote the replication by inter-providers of a way of working similar to the one developed by the leader organization itself, thus beefing up the inter-providers' own supply chain. Another objective of this study is to identify lean practices that support sustainability, as studied by Wee et al. (2009).

To carry out this prospective study, in an area still not sufficiently developed, authors have mainly used qualitative research methods (interviews and study of published practices), which Eisenhardt (1989), Yin (1994) and Gummenson (1991) recommend as appropriate for the exploration of innovative aspects in organizational management. This specific case of a study of sustainability practices applies to a whole supply chain (Mercadona), in which supply chain leader's practices could be a mirror for the rest of members' (inter-providers) supply chain practices. Information has been obtained through: (i) in-depth interviews with three senior corporate managers belonging to Mercadona's top inter-providers (Covap, Sovena and Grupo Siro), (ii) analysis of published data (including analysis, forums, conferences, papers,…).

Regarding in-depth interviews, all of them have been performed during the last two years using semi-structured surveys in a minimum of two meetings per person; questions were mainly focused on collecting their substantial experience.

3 Mercadona's Supply Chain Analysis

3.1 The Business Model

Mercadona's business model has been developed as an efficient way to provide consumers with household products at a price that they considered attractive. In 1993, after rejecting offers to sale the company, owner decided to implement what he called a "TQM model" as the basis of all operations within the organization.

The company moved from a pricing policy based on promotions, to a model where customers could find "always the best prices", in a strategy characterized by quality (in everything linked to customers) and continuous improvement (Ton and Harrow 2010; Blanco and Gutierrez 2010). Mercadona forsook promotions and remained committed to stable prices for its customers, based on long-term agreements with suppliers (Caparrós and Biot 2006). This strategic movement was a revolution, as the former business model was based on maintaining profitability supported on the three pillars that the retail sector had traditionally considered as their profit's basis: variable prices, suppliers pricing negotiation and temporary employees. While introducing a low-price model through its Distributor Brands, Mercadona launched a bunch of measures to reduced "waste" and discontinued any product or activity that did not provide value to its customers, in line with well-known "lean" practices.

Mercadona developed their own Distributor Brands and traded them at a discount of 20–30% below the manufacturer's brand. The phenomenon of Distributor Brands or "private labels" is not a unique strategy of Mercadona, since the vast majority of its competitors also apply it, such as Lidl, (the white label in 2013 accounted for nearly 79.6% of its sales in Spain) and Alcampo (in 2014, 19.3% of its turnover is attributable to private labels). But Mercadona used this practice to develop branded products manufactured by its selected inter-providers, while implementing many actions to attain a superior customer recognition in quality and safety through inter-providers' involvement in quality improvement. Mercadona's business model reflects how the customer is the center of all the efforts by employees and inter-providers through a high quality vision and lean (no any waste is allowed) practices.

Each participant plays a clear role in the fulfilment of their promise to customers. In 2014, they started a further integration to "fresh products" suppliers, such as fishermen and farmers, within a project called Caspopdona (Mercadona 2014). This means that they are improving the entire supply chain, from the fishing boat to the consumer and this could be a very innovative step forward and could even be categorized as revolutionary in an industry in which, until now, lack of coordination and of common objectives has prevailed. Mercadona's business model seeks constant innovation throughout the supply chain and wants, as its ultimate aim, to achieve a "sustainable supply chain". The company is still convinced that there is a clear "opportunity to lay the foundations for growth in the primary sector, enabling those who contribute value to the process to profit, and thereby strengthening social equilibrium in every link of the chain" (Mercadona 2012, 2014).

3.2 Supply Focus: Efficiency and Service Based on Alliances

Mercadona quality commitment to customers is closely linked to the long-term commitments that the company keeps with its suppliers and a strict compliance with food safety standards. They use a system of supplier's categorization, and among them there is an elite group, the so-called "inter-providers". They are perfectly integrated into the Mercadona's business model and their relationship is "forever". Examples of this elite group include partnerships with Sovena (oil), COVAP (milk) and Siro Group (cookies). When analyzing the skills that these inter-providers have developed in this relationship, outstanding performance could be reported in: (i) greater focus on excellent quality, (ii) tight control of processes, Mercadona's strategy with their inter-providers does not allow the slightest area of waste likely to mean a higher cost, with subsequent impact on the final price; suppliers are required to systematically analyze potential improvement areas, and (iii) collaboration in the supply chain integration plan launched by Mercadona with tier two and tier three suppliers, as previously described, which extends till raw materials' suppliers. This obliges inter-providers to develop upstream extra work in order to set quality standards and control their supplier processes, a practice that means additional effort, collaboration and control. One result of this initiative is the pioneering "Girasoles project", which involved participation of 2800 farmers.

Proof of its success are the 690,000 annual pig heads from more than 140 local farmers supplied to Casa Tarradellas, or daily delivery of more than 370,000 l of milk, by 1400 farmers, to Lactiber/COVAP/Iparlat and rice production agreement between Arrocerias Pons and 26 farmers. They are engaged in a double quality guarantee by labeling their own brand on the packaging as proof of commitment. Mercadona wants the consumer to know who produces each item, thus keeping the supplier involved in "the promise to the customer". Mercadona expects from suppliers a continuous improvement process and asks them to replicate throughout its supply chain Mercadona's best practices, keenly aware that any provider's inefficiency is ultimately reflected in its service. The inter-providers conducted, as agreed in their annual improvement plans, significant investments in new facilities and processes improvement as part of the policy of "cross-innovation". To disseminate the best practices knowledge through inter-providers, they have organized an association called Foro Interalimentario whose ultimate aim is to improve their supply chain efficiency.

3.3 Environmental Practices

Within the concept of sustainability as it has been defined earlier in this document, all the practices linked to "waste reduction" are particularly important, since waste could adversely affect both the environment and the economic performance of any company. In this area their focus has been mainly on: (i) improved product design (using "eco-design" practices such as reducing the thickness of the glass bottle while maintaining the security and functionality, or changing the design (from round to square in oil bottles to increase pallet capacity), use of compacted cellulose packaging to reduce the volume of waste) (ii) improvement in the production process (boosting the investment of its inter-providers on processes that use less energy and generate less waste; for example, the Siro group has created a company department to reuse the waste generated in the biscuits production for use in animal nutrition) and (iii) logistics management (Tetris software is used to optimize the trucks' loading in the flow between stores and shops), using trucks that supply stores for reverse logistics (including pallet and packaging), use of equipment specifically designed to minimize noise in the store's midnight downloading (in areas where daytime download would be slow and complex) and using recycled plastic pallets.

3.4 Employees

Employees are another pillar within their "TQM strategy". Approximately 76,000 employees, working in the company as per early 2016, have a labor environment that they recognize is very different from other retailers. Mercadona has a particular way to understand relationships with workers and also encourages the implementation of these practices in their inter-providers. Worldwide retail industry policy is focused on attaining the greatest possible flexibility through employees working with constantly changing schedules, temporary contracts and low wages. However, Mercadona sees this relation very differently because its employees have permanent contracts, receive a month of training while joining the business, family reconciliation (i.e. not working on Sundays), and their salaries are also above the industry average. They do not look for people who do routine work in a particular job but versatile people, even capable to act as "customer's prescribers", so they know the products and advise customers how to use better. Mercadona employees are asked to listen to the customer and propose profitable business practices (Hanna 2010). Employees have social benefits higher than those established in labor standards. The culture of effort and merit is the basis of the organization and the company (Ton and Harrow 2010).

4 Conclusions

According to what stems from the analysis, it is clear that Mercadona's model is organized around the customer, which the company calls "the boss", ensuring that he will get the best market price, an optimal price/quality ratio and a reasonably wide product range. This policy is supported by the implementation of concepts that could be considered as pertaining to the "excellent operation management principles of Lean Operations". Their focus on waste elimination (considering as such everything that does not add value to the consumer) and their obsession with continuous improvement are evidences that the principles of lean operation are present in the model. On top of that, partnership development, as a way to use all the skills and competencies of their supply chain members, enable them to boost

Fig. 1 Mercadona's sustainability model. *Source* Own elaboration

their "supply chain sustainability". All this is supported by a specific and characteristic people management style, quite different from the classic approach in the retail industry; it does not seek to squeeze people with methods such as extreme flexibility, but rather to maintain a balance between flexibility and personal life reconciliation. According to this analysis, Mercadona's supply chain could be considered as an example of fulfilment of the main "triple bottom line" requirements, as indicated by Elkington (1998, 2004). The relationship model that emerges through the collaboration's network of over one hundred inter-providers could be represented by the following illustration (Fig. 1).

It is possible to infer that they have created a solid model and one of the reasons for this strength may be based on its long term objectives and strategy. They understood that their strategy is supported by their key inter-providers, which have been linked to their supply chain improvement practices. Their current and future business is built on long term partnerships (alliances), lean operations strategy and practices (they named TQM) and a clear focus on their inter-providers continuous improvement. Inter-providers are strongly requested to mirror and apply Mercadona's best practices in terms of quality, cost performance through waste elimination, process stability, long-term vision and people involvement to maintain their status and contribute to the Mercadona's aim to be a "sustainable supply chain".

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The Executive's Personal Characteristics Influences on the Strategic Decision-Making Process: Does the Mental Model Matter?

Flávio Bressan

Abstract The strategy concept has no definitive concepts and models, and it is not without controversy. Its approaches sometimes seem to oppose, sometimes seem to complement each other. In this way, researchers have long been attempting to understand the concepts of strategic choice and decision. This issue may be approached through the executive's mental model, the characteristic models of perceiving, processing and using gathered information. The relationship between executive's mental model and strategic choices and decisions is done theoretically by examining the mental model under temperament proposition. Author concludes that the executive's mental model—operational or strategic—may explain their strategic choices and decisions. This understanding of mental model can prevent biases in the strategic analysis and promote a best strategic choices and decisions

Keywords Executive strategic choices · Executive strategic decision process · Executive mental models

1 Introduction

Strategic management is a multifaceted phenomenon related to the executive running business, the managed company, and business environment (Brazeal et al. 2008). It is the lone human activity able to transform human efforts and competences in wealth (Drucker 2007; Koellinger 2008). Taken together, these areas bring strategic questions to the discussion. As research indicates, the very nature of strategy takes into account the business environment, executives' personality (Miles and Snow 1978; Gallén 1997; Mintzberg et al. 2000; McCarthy 2003; Michaud et al. 2003; Coakes and Smith 2007) and their choices and decisions (Stumpf and Dunbar 1991). The search for an understanding of the executive management

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process has itself theoretical and practical values. On the theoretical focus, one main contribution refers to the identification of the type and the extension of the executive's personal characteristics—the mental model—influence on the strategic choices and decisions that will determine the enterprise fate. These characteristics will affect the perception and the understanding of environmental challenges, and opportunities and by consequence, the strategic decision making (Daghir and Zayde 2005; Gallén 2006). Thus by identifying the type and extent of this influence on the fate of the organization it can serve as a basis for designing of an explanatory model in the context of business management field (McCarthy 2003).

On practical view, executive's choices and decisions may be a way to the broadening of business, for introducing innovations or new solutions for market needs. They may enlarge the business frontier and create new business or markets, which may generate economic development, and new employment opportunities and new enterprises (Bosma 2013; Nga and Shamuganathan 2010), and to minimize the social and political causes of poverty (Mensah 2010). This paper presents a basic review of the strategic concept, and the choices and the decision making process, and the mental model proposition. Its purpose is to establish a link between executives' mental model and her or his strategic choices and decisions and to point out some propositions as a guide for empirical research.

2 Understanding Strategy

Literature presents numerous definitions, as well as many approaches to strategy (Porter 1998; Mintzberg et al. 2000). Strategy can be seen as patterns that integrate the main policies, norms, goals in a coherent and consistent system (Hax and Majluf 1997). Strategy formulation is not simply an exercise in rationality, but it reflects experimentation, exploration, intuition, instinct and learning (McCarthy 2003). It becomes a delicate balance between motivations, the learning acquired with experiences, and the modeling of new ways for a business to succeed. In this paper, strategy is defined as

> a coherent, unifying, and integrative pattern of decision that determines and reveals the organizational purpose in terms of long term objectives, selects the businesses the organization is in or is to be in, attempting to achieve a long term sustainable advantage in each of its businesses, by properly responding to the opportunities and threats in the firm's environment, and the strengths and weaknesses of the organization, engaging all the hierarchical levels of the firm and defining the nature of the contributions it intends to make to its stakeholders" (Hax and Majluf 1997, p. 38).

This concept denotes that corporate will follow a reasonably coherent and stable pattern in its strategic choices and decisions, but do not necessarily doing it by the adoption of a formally structured plan (Wiesner and Millet 2012; Ensign 2008). Many firms usually do not have a tradition or routine for addressing strategic issues by developing a formal strategic planning. The absence of a formal process does not mean the inexistence of any strategy but it may mean that the executive is open, flexible, responsive and willing to learn (Hax and Majluf 1997).

3 The Executive Decision Making Process

Decision making process involves the selection of a specific course of action that is supposed to bring enterprise desired results (Gibcus et al. 2008). As a strategic activity, it is a process that leads to the choice of goals and resources and people, and the way which they are effectively deployed. As strategic, they may be defined as programmed choices and/or reactions about business environment issues that affect the survival, thrive, well-being and the nature of organizations (Shoemaker 1995). Mistakes on strategic decision may put the enterprise under the risk of failure or going bankrupt (Balta et al. 2010; Woods and Dicson 2010; Ensign 2008). Every executive is expected to adopt a planned and rational approach to decision-making. In this way, one basic assertion to the field studies on decision-making was the rational human being, which is coherent with the economy concept and the Scientific Administration. This rational man is able to analyze all data and alternatives for a given situation and then makes a perfect rational decision by choosing the best solution that optimizes the desired results. As Simon put it,

> This man is assumed to have knowledge of the relevant aspects of his environment which, if not absolutely complete, is at least impressively clear and voluminous. He is assumed also to have a well-organized and stable system of preferences, and a skill in computation that enables him to calculate, for the alternative courses of action that are available to him, which of these will permit him to reach the highest attainable point on his preference scale. (Simon 1955, p. 99)

However, as a large stream of research on cognitive biases in decision making process has consistently demonstrated, executives are not perfectly rational but boundedly rational. Under rationality, executives make decisions on a logic basis, by analyzing each alternative for finding the best choice in a known and scanned environment. It does not admit ambiguity. It has as a basic presupposition that executive has or believe to have the mental capability to know and analyze in a rational way all data and alternatives for the situation under analysis (March and Simon 1967). In doing this, they will formulate a utility equation that enables them to choose the alternative that will bring the desired results.

This full rational assumption has strong and opposite argument. Many times our decisions are governed by our unconscious, which influences and distorts our perception (Freud 1975). Most problems an executive faces are very complex and are made up of far more relevant variables for the decision at hand than an executive may comprehend. So, in contrast of the rational man, there is the administrative man proposition which stay that the decision-making process may be characterized as a bounded rationality process (Schilirò 2013). Bounded rationality refers to the executives' limits in their abilities to perceive and interpret a large volume of pertinent information for decision making (Simon 1979, 1955). In this way, executives will select the alternative that best fit with the personal values and beliefs, or at least, a boundedly rational decision (Tiwani et al. 2007).

As rationality is emphasized in the educational process and work situations (Pink 2007), there will always be a rational drive in every decision, but the executive's bounded rationality will act as an obstacle to a perfectly rational decision-making process. Furthermore, executive's personal temperament in conjoint with formal education and experiences may bring meaning and color to the problem or context that she or he is facing and may act as a strong obstacle to a perfectly rational decision. This features allied to the executive's feelings and expectations may interfere in the perception process in a way that important data would be considered without relevance, building a gap between the actual and perceived reality.

Another restrictor factor to the genuine rationality is the occurrence of the situation requiring an ad hoc decision that may present ambiguity or may contradict values that are espoused by executive (Wolcott and Lippitz 2007) and may cause a cognitive dissonance process (Festinger 1957). On the other hand, personal differences lead executives, in spite of high intelligence quotient and competence and education level, to perceive the same reality from different angles, with different characteristics demanding different decisions and actions (McCarthy 2003). In this way, people with little focus on concrete and factual aspects of the reality will tend to look at the opportunity from a positive side than a negative one (McCarthy 2003) and to see fewer risks and threats in the strategic implementation and be more risk tolerant than others (Gallén 2006; McCarthy 2000; Keller et al. 2014).

In this way, it may be said that what will be perceived as the true reality by one executive may be very different from the other one because the executive's perception and analysis processes may suffer influences that other don't (Pellegrino and Carbo 2001). This may lead different executives to take different strategic decisions facing the same context. Many researches on decision making, by focusing on the role of the preferred way for perceiving, organizing and using in-formation, have pointed out that people act on their preferred cognitive style which may drive to a specific strategic choice (Gallén 2006). These factors seem to be a strong cue that perception, organization and use of information—mental model—are critical in the strategic choice and decisions. So, what is the interaction between the decision-making process and the executive's mental model?

4 Strategic Choice, and Decision Process and Mental Model

According many researches, the perception does play a major role in the decision making process. They suggest individual's perceptions, rather than objective reality, explain the decision to start a new business, for example (Krueger and Brazeal 1994). Perception directly influences enterprise successful performance because to survive and grow it is necessary to anticipate or react in facing business environment opportunities. Because of this, the search for understanding on executive's way of perception and use information and perception influence on strategic choices and decisions becomes a relevant issue for developing some propositions to support strategic choices and the decisions (Gallén 2006). The fact of an alternative or course of action is perceived as desirable leads us to a question related to the factors leading an executive to perceive the same situation in a different way from others (Gallén 2006). So one can ask: How one can explain executives' strategic choices and decisions? The answer may be found in the mental model approach, which is widely recognized as an important determinant of individual behavior which manifests itself in executive's strategic choices and decisions (Senge 1994). But, what the mental model is?

4.1 *Mental Models and Temperaments*

Mental models may be described as the typical model of perceiving, processing and using information gathered. They are neither wrong nor right. Different mental models may lead to different strategic choices facing same business environment. By knowing the executives' mental models, one "can assume that their processes of strategic choice and decision making are different if their perception and judgment are different from each other" (Gallén 2006, p. 119). Some executives are only interested in what is; Others are more able to accept the new, untested ideas about what might be (Hambrick et al. 1993). This proposition is in according to the temperaments approach (Keirsey and Bates 1978). Temperaments are derived from one's preferred modes of perception and behavior in facing many life situations and are a useful way of grouping preferences. They made possible to make consistent previsions on one's preference and behavior, on how one manages (Kroeger et al. 1992), and about his/her mental model. Differences in perception—concrete/sensorial and global/intuitive (Jung 1991)—are the first to be considered.

The concrete perception mode points to a preference for collecting factual and concrete data and then deciding what to do: organize them or continue to look for more information. The preference for global perception mode means a preference for collecting abstract or conceptual data and then will organize them in a rational way or by considering people's values and interests (Keirsey and Bates 1978; Silva 1992). By considering these preferred modes of perception and behavior in facing many life situations (Silva 1992) and translating the "what it is" as factual focus on "here and now" and "what may be" as "possibility for the future" (Hambrick and Mason 1993) it became possible to make a synthetic classification of mental model into operational mental model (OMM) and strategic mental model SMM).

4.1.1 Operational Mental Model (OMM)

OMM is characterized by the focus on what is going on and by the search for precision, reliability, efficiency, prudence and discipline, and conformity. She or he is practical (Keirsey and Bates 1978) and demonstrates high focus on problem solving rather than finding it, and tend to reduce problems occurrence by improving and maximizing the process efficiency. She or he has a preference to make plans

<table>
<tr>
<td rowspan="2">Operational Mental Model
This mental model is characterized by her or his focus on what is going on and by the search for precision, reliability, efficiency, prudence and discipline, and conformity. She or he is practical and demonstrates high focus on problem solving rather than finding it and tend to reduce problems occurrence by improving and maximizing the process efficiency, under the existing conditions; she or he has a preference to make plans and is happy with the plan accomplishment. Quick to decide, but once a decision is made, this is not a problem for her or him. The day-to-day activities of an operation-minded person are driven by responsibility, obligation and duty, and he or she rarely challenges the norms and policies. As to this person the next step is to apply the information to daily activities, she or he may do things in a planned way – Implementer – or in an improvised way – Pragmatist.</td>
<td>Implementer prefers decisions over options; he or she is traditionalist, stabilizer, consolidator; he or she works from a sense of responsibility, loyalty and industry and learns in a step-by-step way with preparation for present and future utility. She or he prefers the decision over possibilities, concrete over the abstract and order over flexibility; he or she tends to focus on current, here-and-now issues, but lets experience guide him or her in solving problems.</td>
</tr>
<tr>
<td>Pragmatist prefers action over reflection, responding over planning; she or he is a fire fighter, troubleshooter negotiator; she or he works via action with cleverness and timeless - give him or her a problem to fix and she or he is in his or her element. She or he learns to meet current needs through active involvement. She or he possesses the most pragmatic mental model and uses her or his sense of the obvious to scan the environment to determine the best way to outmaneuver an adversity. She or he is expeditious in handling of the out-of-ordinary and the unexpected.</td>
</tr>
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Fig. 1 Operational mental model. Source: Keirsey and Bates 1978; Kroeger et al. 2009; Silva 1992

and is happy with the plan accomplishment. Her or his day-to-day activities are driven by responsibility, obligation and duty; he or she rarely challenges the norms and policies. The next step is to apply the gathered data to daily activities: OMM may do things in a planned way—implementer—or in an improvised way—pragmatist (Fig. 1).

Implementer is traditionalist, stabilizer, consolidator, and prefers decisions over options or possibilities; he or she works from a sense of responsibility, loyalty and industry and learns in a step-by-step way for the present and future utility. She or he prefers concrete over the abstract, and order over flexibility, and tends to focus on here-and-now issues, but let's experience guide him or her in solving problems.

Pragmatist is a fire fighter, troubleshooter, negotiator, and works via action with cleverness and timeless and prefers acting over planning. She or he uses the sense of the obvious to scan the environment to determine the best way to outmaneuver an adversity. She or he is expeditious in handling of the unexpected.

4.1.2 Strategic Mental Model (SMM)

SMM takes information through the sixth sense, by focusing not on what is but on what may be. He or she will probably describe himself or herself as innovative (Keirsey and Bates 1978), and may be characterized as disorganized by the low adherence to norms and rules. He or she is able to think strategically and to bring innovative solutions to daily problems. Visionary and architect of change, she or he is imaginative and analytical, exploring all possibilities inherent in any situation and directing their energy toward building systems for the future. SMM works on ideas with ingenuity and logic, and may be sensible to people or privileges rationality. The next step is to use the information in the decision-making process: it may be taken in a rational way—strategist—or in a value-based way—energizer (Fig. 2).

Strategist prefers to look at the big picture rather than details in search for possibilities to build new systems or to solve problems; She or he tends to make

<table>
<tr><td rowspan="2">Strategic Mental Model
This mental model takes information through her or his sixth sense, by focusing not on what is but on what may be, and looks for meaning in all things. A person with this mental model will probably chooses to describe himself or herself as innovative, and may be characterized as disorganized person by the low adherence to norms and rules and structures, and many times this person is considered undisciplined. He or she is able to think strategically and to bring innovative solutions to daily problems and issues. Visionary and architect of change, she or he is imaginative and analytical, exploring all possibilities inherent in any situation and directing their energy toward building systems for the future. She or he is a visionary and works on ideas with ingenuity and logic. She or he learns by an impersonal and analytical process for personal mastery, and may be sensible to people or privileges rationality. By considering that the next step for Strategist is to use the information in the decision making process, one may know if his or her decision will be taken in a rational way – Strategist – or in a value based way – Energizer.</td>
<td>Strategist prefers to look at the big picture rather than details in search for possibilities to build new systems or to solve daily and potential problems; she or he tends to make decisions based on logic and objective-analyzes and in an impersonal way. She or he is a visionary, architect of systems, builder, and works on ideas with ingenuity and logic, is imaginative and analytical, exploring all the possibilities in any situation. She or he learns by an impersonal and analytical process for personal mastery, and believes that an organization's daily activities must be consistent with its mission and directs her or his energy toward building systems for the future.</td></tr>
<tr><td>Energizer tends to make value-based decisions by considering possibilities, and others' interests and wishes. In this way, she or he is catalyst, spokesperson, energizer, and works by interacting with people about values and inspirations; she or he prefers to look at the big picture rather than details in search for possibilities for people, and learns for self-awareness through personalized and imaginative ways. Humanist people are enthusiastic and passionate in championing people, causes and anything new.</td></tr>
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Fig. 2 Strategic mental model. Source: Keirsey and Bates 1978; Kroeger et al. 2009; Silva 1992

decisions based on logic and objective analyzes and in an impersonal way. She or he is a visionary, architect of systems, and works on ideas with ingenuity and logic. She or he is imaginative and analytical, exploring all the possibilities in any situation; He or she believes that the daily activities must be consistent with its mission.

Energizer tends to make value-based decisions by considering possibilities, and others' interests and wishes. She or he is catalyst, spokesperson, and works by interacting with people on values and inspirations; she or he prefers to look at the big picture in searching for possibilities for people. Energizer is enthusiastic and passionate in championing people, causes and anything new.

In this way, mental model and temperament approach appoint for the potential for future research related to the executives' strategic choices and decision making process, and, in this way, for addressing the relationship between the strategic choices and strategic decision process.

5 Discussion and Conclusion

The main purpose of this study was to make a theoretical link between executives' strategic making process, their strategic choices and the influence of executives' mental model in the strategy formulation and the way of running the enterprise. Based on the previous researches, it was made possible to point out same theoretical correlations between both mental models and strategic choices. As an alternative approach, by emphasizing the role of the perception process in the choices and decision-making process, this study proposes the mental models (Keirsey and Bates 1978), as having great influence on executives' choices and decisions (Fig. 3).

Theoretically, this propositions signs an interesting research field because, by proposing the mental model approach, this study presents a model that may help to explain how an executive perceives the business environment and, in doing so, how she or he uses his or her mental model to make choices and decisions. As the

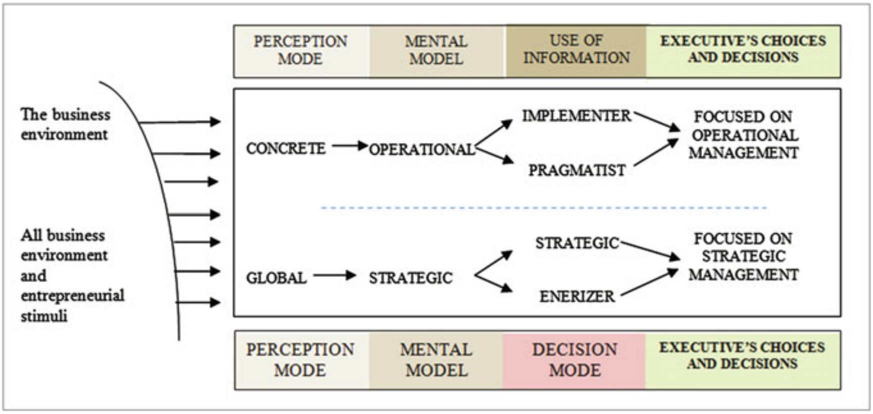

Fig. 3 Mental Models and Executives' choices and decisions. Source: Author's Mental Models proposition

business environment requires executives to bring forward or reacts to challenges and threats and the opportunities that appear and disappear, by knowing the one's mental model, it may be possible to make previsions about her or his chance to succeed in the strategic management in running the enterprise.

According to the proposition, it may be said that if an executive presents an operational mental model, her or his choices and decisions probably will be focused on operational and daily issues of managerial process, planning and managing for budgeted results. He or she will demonstrate high focus on the problem solving rather than finding it and will tend to reduce problem occurrence by improving and maximizing the process efficiency.

An operational minded executive will expect business environment strengths and opportunities and competitive issues to be understood, explained, and controlled through the repertoire of the frameworks and models that he or she has assimilated. More importantly, he or she seems to develop a blind spot or is unable to correctly decipher those aspects of the business world that reside outside of their mental model (Mukherji and Mukherji 2003). When dealing with strategic issues, her or his way of thinking is that "in the future things are going to be like in the present".

This is especially critical because the fast-paced and complex business environment do not fit operational mental model that perceive the business environment as organized, factual and stabilized. Changing business environment imply that managers must be ready to consider new choices, to take risk, and make decisions and develop and implement new strategies and different ways of running business. Paradoxically, (Dunbar et al. 1996) when an operational manager faces turbulence in the business environment, the mental model let him or her to assume contextual stability and to a preference for incremental adjustments in keeping with this assumed stability.

By another side, it may be said that if an executive presents a strategic mental model, she or he take the information through a global perception process by focusing not on what is, but on what may be, and will look for meaning in all things. As a natural strategic thinker, her or his choices and decisions will have the strategic management as the main focus. She or he probably will look for and bring new and innovative solutions for business daily problems and issues. This executive tends to be a visionary and imaginative and analytical, exploring all possibilities inherent in any situation and directing their energy toward building systems for the future. She or he will work on ideas with ingenuity and logic.

He or she will take into account that strategic administration inherently requires understanding and management of the two-way relationship between capability—resources and components—and organizational purpose, and the understanding of how different organizational components can generate strategic advantage and the effectiveness that will have useful strategic and operational consequences for the company. For example, in a longitudinal work on new business development, Stevens and Burley (2003) stated that personal characteristics—mental model—of individuals involved in early stages of new business development have been found to be as important as the process of development itself, and that strategic minded analyst have generated 95 times more profit than those operational minded analyst.

This proposition appoints for the potential of mental model for future research related to the competitive business environmental analysis and business strategic management. It may be an open door to a new perspective on how to explain executives' strategic choices and decisions and creates avenues for future empirical investigation on this issue. In this way, we believe this proposition will inspire others researchers to design and conduct research projects to address the impact of mental model in the executives' success to bring about new insights on executive business management. Under the practical implications, this proposition may be of interest for the executive selection and development processes. It may be relevant to the talent development program, and for the career and succession processes. In this way, by knowing one's mental model, it may of value in matching the executive mental model with the executive positions to be occupied in the company.

It may be said that by knowing the executive's mental model, it will enhance the Board competence for making previsions about executives' chance to succeed in the strategic business management in running the enterprise. In this way, one will be in a position that made possible to lead strategically, and help the corporation to run business in a safe way in the turbulent business environment by adequately facing challenges and addressing opportunities it may present.

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Components to Construct a Business Model Innovation Under a Product-Service System Approach in the Aerospace Industry Through Analytical Hierarchy Process

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Abstract This paper uses Analytical Hierarchy Process (AHP) methodology to perform a pairwise comparison between the components of a business model aiming to select which of them are the most important to innovate a business model from a manufacturing to a product-service system approach in the aerospace industry. The results indicate Value, Strategy and Organization as the most important components in order of importance, followed by Sustainability, Process, Resources and Stakeholders.

Keywords Product-service system · AHP · Business model innovation · Aerospace

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1 Introduction

Business Model Innovation (BMI) can be defined as a novel way of how to create and capture value, which is achieved through a change of one or multiple components in the business model (Teece 2010). These components constitute the business model (BM) framework describing what a business model is made-off (Fielt 2011) and indicating how they relate to each other. One of the components or elements found in the literature is value (Chesbrough and Rosenbloom 2002; Osterwalder and Pigneur 2010). Value is provided to customers through services rather than products (Barquet et al. 2013). Considering that, it has been rising opportunities for companies innovate their BM from a product oriented effort to a service oriented one or even integrating both in order to secure long-term growth and to remain competitive in the marketplace (Jacob and Ulaga 2008).

Since products start to miss differential between the manufacturers due to the development of new technologies that permit to copy or improve the good offered by the competitor, BMI seems to be an alternative to try avoiding this kind of competition. Including the aspect of service that is characterized by a more personal treatment with the customers, the new BM considering the joining of product and service offers a particularity that is more difficult to imitate.

Studies have been indicating opportunities for joining product and service in the aerospace industry (Correnti et al. 2007; Johnstone et al. 2009; Schneider et al. 2013). Although this sector is recognized by its intensive technology, R&D activities investment, specialized work force and high value added, Lorrell (as cited in Johnstone et al. 2009) states that this industry is generally characterized by low rates of production, small total outputs and high per-unit costs. Furthermore, the authors consider some drivers that can influence the integration between products and services in this sector. One of them is related to the demand side, which core competencies and cost control are aspects more important than a tangible good. In their point of view, airlines companies could be dedicated only to their core task of carrying people and cargo. Doing so, the companies would outsource the other activities and even not acquire the planes. Based on that, the present paper aims to answer the following question: *Which components are the most important to design a BMI under a perspective of product-service system in manufacturing aerospace industry?*

The objective of this study is identifying which component is more important among others in a way that future researches can focus on it and analyze how its changing can influence the structure of the BM. Besides, there is a gap in the literature indicating an opportunity to develop a better understanding of how this kind of BM is implemented and structured, due to the lack of a more detailed understanding about the value proposition and the necessary resources and processes designed to enable an efficient service launched on the market (Reim et al. 2015; Gaiardelli et al. 2014; Bullinger et al. 2003).

2 Characteristics of Product-Service System Components

Some aspects of product-service system (PSS) have arisen as components of a BM framework. Value, for instance, constitutes the central element within the framework of PSS, considering that manufactures will design product-service solutions only if the value provided by the service is more relevant than in traditional business (Maussang et al. 2007). There are two aspects of value: the value in the point of customer view (e.g. the value proposition or value creation) and value in the company view (e.g. the value capture). The second is a consequence of the first. If the company satisfies customers' needs, attending their requirements, the customer will pay for what he perceives as value. Consequently the company will make money, which will indicate revenue and profit results.

Besides value, others aspects must be considered to construct a BM framework oriented to PSS. Organization, Stakeholders, Process and Resources are the four elements for high-performance business proposed by Arthur D. Little (Kotler 2003). The organization consists of structures, policies and corporate culture, considering new capabilities, metrics, incentives, changes from transaction- to relationship-based (Oliva 2003) and information technology support (Bullinger et al. 2003). Stakeholders encompass customers, employees, suppliers and distributors. Processes are related mainly to the core business processes, which comprise new-product development, customer attraction and retention, and order fulfillment through cross-functional teams with excellent capabilities. Finally, the resources such as labor power, materials, information and energy, which can be the firms' ownership or obtained outside, are the infrastructure necessary to put the business working.

Researches in PSS also consider sustainable issues since services can extend the product's life cycle (Vandermerwe and Rada 1988). Manufacturers become more responsible for upgrades and material recycling (Mont 2002), which contributes to a more conscious product usage and increases resource productivity (Aurich et al. 2006). However, the consumers can value the environmental issue, notice the offer of an ecological product but not acquire it if the price is not affordable (Bertolini et al. 2012). What must be taken in account is its meaning and benefits in different contexts (Boons 2013), which will indicate different necessities and interests for customers and providers in the BM. For this reason, the local context and the market characteristic must be considered when a firm is evaluating to change its BM.

Although strategy can be controversial in terms of differences related to BM concept (Chesbrough and Rosenbloom 2002; Shafer et al. 2005), Timmers (1998) states that a BMI in itself does not yet provide understanding of how it will contribute to realize the business mission of any of the companies who is an actor within the model. One must know the marketing strategy of the company in order to assess the commercial viability and to understand how its competitive advantage is being built. According to Casadesus-Masanell and Ricart (2010), BM is the logic of the firm to operate and create value for its stakeholders; strategy is the choice of BM

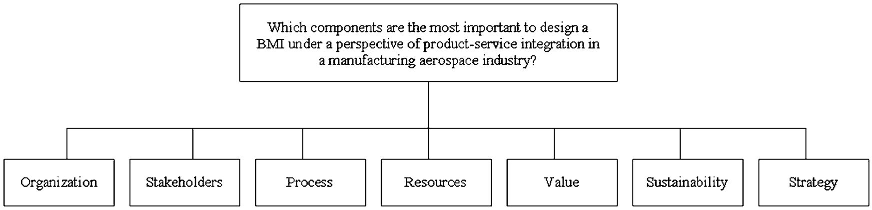

Fig. 1 Hierarchy of criteria to design a BMI

through which the firm will compete in the marketplace, being an action plan designed to achieve a particular goal.

Based on the components characteristics aforementioned, Fig. 1 illustrates the hierarchy of criteria considered to analyze and evaluate the objective of this study and answer our research question. Next section, we explore the methodology employed to identify the components that can be part of a BM in the aerospace industry in the context of PPS.

3 Methodology

Considering that we found different components in previous section that arrange a BM framework, we aim to identify which of them have the highest priority to conduct a BMI from a traditional BM of a manufacturing company to a BM with PSS characteristics in the aerospace sector.

For conducting the study, it was elected a tool for decision making with multi-criteria, the Analytic Hierarchy Process (AHP). It utilizes pairwise comparisons for a set of criteria to judge the relative importance of one criterion to another in a fundamental scale from 1 to 9, from equal importance to extremely importance (Table 1), through a construction of a square matrix (Saaty 1980).

The judgments are made by experts or decision makers and then synthesized in the use of eigenvectors to determine which variables have the highest priority (Jiang et al. 2011; Joshi et al. 2011). Thus, this tool gives a result with the relative importance of each element and also prioritizes it, evaluating the consistency of the obtained solution.

In this study, the matrix of judgments were structured in an Excel Sheet (Klaus 2013) and submitted to the judges. The process of analysis was done through face interview with a semi-structured questionnaire explaining the definition of each component, how to do the analysis and an overview of the aerospace sector. The judges selected consisted of a sample of six interviewees chosen based on their knowledge and experience in BM, product and service domains and professionals which hold leadership positions in a specific aerospace industry located in South America. Table 2 shows the characteristics of the interviewees. The findings of the judgments are presented and discussed in the next section.

Table 1 Fundamental scale (Saaty 1980)

Intensity of importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another, it dominance is demonstrated in practice
9	Extremely importance	The evidence favoring one element over another is of the highest possible order of affirmation
2, 4, 6, 8	It can be used to express Intermediate values	

4 Findings and Discussion

According to Fig. 1, we have identified the decision hierarchy for the problem with seven criteria as the business model elements in a PSS approach. Based on our research question: "*Which components are the most important to design a BMI under a perspective of product-service integration in a manufacturing aerospace industry?,*" the weights of the criteria to be used in evaluation process were calculated by using AHP method explained in the previously section. The consolidation of the pairwise comparison matrix and the results obtained from that are presented in Table 3 and 4 respectively. Consistency ratio indicates a value of $0.015 < 0.1$, which indicate that the weights are shown to be consistent and they are used in the selection process.

Value, Strategy and Organization have the highest figures, with relative weights of 0.247, 0.206 and 0.193, respectively. On the other hand Sustainability, Process, Resources and Stakeholders have much lower relative weights. It is noted that the majority of the respondents is worried about the impact that this innovation can cause in the value captured by the industry, especially the professionals who hold leadership positions. They believe that only if the change in the BM brings a relevant increase in the revenues, it is justified promoting such innovation. Strategy is also perceived as important due to the guidance it gives to the firm makes any changing in its business. In other words, the firm must give a guideline about which market it should explore to satisfy customer needs. And the organization must be structured with the right hierarchy, policies and culture to be solid enough to conduct the new BM. If the organization is not well prepared on such aspects, it is not possible to have the appropriate resources, process and stakeholders to be part of the implementation. That is why these criteria appeared with less importance in the judges' point of view comparing to Organization criterion. With 0.099 of relative weight, Sustainability indicates a kind of importance since it's believed by the respondents that the environment aspect is a decisive point to some consumers in acquiring a product or service which its producers have a conscious about the

Table 2 Characteristics of the judges

Characteristics	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5	Interviewee 6
Function	Consultant	Professor	Professor	Manager	Director	Vice-president
Operating area	Business models	Product development and service innovation	Product development	Engineering	Commercial	Financial
Time in the function	10 years	5 years	31 years	8 years	3 years	6 years

Table 3 Pairwise comparison matrix

Criteria	Organization	Stake holders	Process	Resources	Value	Sustainability	Strategy
Organization	1.00	4.15	1.44	2.08	0.70	1.42	1.17
Stakeholders	0.24	1.00	0.92	0.85	0.33	0.69	0.46
Process	0.69	1.08	1.00	1.20	0.35	0.83	0.35
Resources	0.48	1.18	0.83	1.00	0.34	1.12	0.43
Value	1.42	3.04	2.84	2.93	1.00	2.88	1.01
Sustainability	0.70	1.44	1.20	0.89	0.35	1.00	0.44
Strategy	0.85	2.20	2.84	2.31	0.99	2.26	1.00

Table 4 Results obtained with AHP

Criteria	Weight	λmax	CR
Organization	0.193	7.116	0.015
Stakeholders	0.074		
Process	0.092		
Resources	0.089		
Value	0.247		
Sustainability	0.099		
Strategy	0.206		

correct use of raw materials. However, even this aspect is considered important, it is not a factor decision for changing the BM, especially in the interviewed point of view from the industry group. Generally, environmentally friendly products or the services offered with a product which its manufacturing or maintenance process have environmental conscious tend to be more expensive both for the producers and for the customers.

5 Conclusion

This study could show that the components for innovate a manufacturing BM to start to offer a service in the aerospace industry in order of importance are Value, Strategy, Organization, Sustainability, Process, Resources and Stakeholders. One limitation of this analysis is that it was not informed to the judges what kind of service would be offered by the company. It was just explained that a manufacturing company would start to offer the service through the use of its main product instead of selling it, but not the configuration and the characteristics of the new business. With more detailed information about the business would influence the interviewees to prioritize the criteria. Besides, we have considered a multi-disciplinary sample to make the judgments among specialists and researchers in BM and PSS, and professionals in leadership position from an aerospace industry. If the questions were presented to a unique group, the results could be different. Other limitation is that it was considered only one database to search the PSS characteristics. Other databases can be used and indicate different components to construct a BM in the PSS context, orienting the analysis process of importance level of the components identified.

For future researches, we propose to apply the AHP with more information about the new BM configuration and characteristics. Also, we propose a study focusing on how the components would influence the result of the new BM or how they would impact the construction of the new business and the expected results for a specific company. It is suggested to focus on one or two components with the highest relative weight to conduct a study analyzing their main aspects of changing in the new BM proposed.

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Depicting Big Data: Producing a Technological Profile

Iñaki Bildosola, Rosa Rio-Bélver, Ernesto Cilleruelo and Gaizka Garechana

Abstract Emerging Technologies are having a huge impact in the income statement of current enterprises and therefore they must be adopted as soon as possible. Thus, any attempt to introduce the characteristics and evolution of this kind of technologies is helpful for decision makers. In this sense, this paper aims at depicting *Big Data*, one of these cutting edge technologies, by obtaining a complete profile of it and generating the bases for a valid forecast. The approach is made within the Information Structuring and Technological Forecasting fields, with the application of several methods, namely: Text Mining and Natural Language Processing, Visualization Techniques and Trend Analysis.

Keywords Big data · Text mining · Information visualization · Trend analysis · Forecasting

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1 Introduction

Emerging technologies have a huge impact in current enterprises. Many attempts have been made at mapping the knowledge of a given technology and determining its possible evolution, which is no more than completely depicting that technology. *Information Structuring* should be the first phase in this process, where, in addition to the classical methods such as Scientometrics and Bibliometrics, which are based on Text Mining technics, new ones are appearing based on Natural Language Processing (NLP). NLP is the attempt to extract a fuller meaning representation from free text (Kao and Poteet 2007) and Web (Content) Mining (Cooley et al. 1997), which tries to analyse and extract valid information from the content of web pages. In addition to this, several visualization techniques are used for depicting scientific fields, with the use of Maps of Sciences, in which the items on the map refer to themes in the mapped field (Noyons 2001).

The second phase is about *Technology Forecasting*, which is used to predict the future state of a technology. Many methods and models can be found within this field, which are commonly grouped into two families based on their characteristics: quantitative and qualitative methods. These methods must be fed with valuable data in order to generate valid predictions, and this is why they are (or should be) applied after a consistent information structuring process.

This paper is centered on the first phase of all this process. The research approach is that proposed by Bildosola et al. (2015), which was structured in eight steps and was already applied to Cloud Computing technology in Bildosola et al. (2015B), thus the current work will be focused on Big Data technology. In the case of the present application some improvements have been added to the approach, among which it is worth pointing out the followings: the use of Natural Language Processing (NLP) method in order to extract a fuller meaning representation from free text; and the use of *Google Trends* tool in order to add a counterpoint to the trend analysis classical methods. The authors have not encountered studies of this kind in extant literature, with which the depiction of Big Data technology is obtained. The paper is divided as follows: in section two Big Data technology is described without deep technical concepts. The third section presents the research approach which is based on three main steps. The fourth section will show the results of the application of the approach to Big Data technology. The conclusions and future work intentions are presented on the fifth section.

2 Big Data

Big Data definitions have evolved rapidly, which has raised some confusion. However, most of the definitions agree on three main characteristics that any data should have in order to be considered *Big Data:* Volume, Variety, and Velocity. Gartner, Inc. gave a nice definition: “Big data is high-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation" (Gartner IT Glossary n.d.). Big data is closely linked to analytics, it seeks to glean intelligence from data and translate that into business advantage. Even if this process is not new, those three characteristics mentioned before are the key to accept the evolution from *analytics* to *Big Data* (*analytics*). It is worth remembering that this technology is strongly related to three other technologies, namely: Cloud Computing, Mobile Internet and Social Networking, which are generating the so called Big Services Era (Zhang 2012).

When it comes to analyse its impact into companies, the extant research in academia and industry shows that retailers can achieve up to 15–20% increase in ROI by putting Big Data into analytics (Perrey et al. 2013). In addition to this, Big Data has the capability of transforming the decision making process by allowing enhanced visibility of firm operations and improved performance measurement mechanisms (McAfee and Brynjolfsson 2012).

3 Research Approach

The structuring of the information is divided into three steps which construct a continuous process where the outcome of each step is the input of the following. The approach has two main objectives: on the one side obtaining a good data base, which will be mined in order to generate all the elements required in the forecasting process; on the other side the generation of a complete profile of the technology, where all the scientific contribution is depicted, in terms of research community description and research content identification. The *VantagePoint* tool was used in all sub-steps where text mining tool was required.

The first step is known as *Retrieving Data and Refining the Search*. All the data must be retrieved from different databases and these databases should be based on Peer-Reviewed (PR) journal articles, which constitute good information sources for tracking scientific activity (Porter and Cunningham 2005). This step aims at refining the data retrieving in order to reduce the noise influence in the profile characterization and its conclusions; such reduction was sought through refinement in terms of excluding articles not directly related to Big Data technology field research. This step is carried out by the introduction of Boolean conditions in the search queries, directly typed in the tools of the online databases, which in the case of this study were Web of Science (WoS) and Scopus.

The second step consists of *Cleaning up of the Refined Dataset*. The records containing bibliographic information must be imported and integrated in a unique database where duplicated records must be removed. In addition to this, and before mining the data, some fields have to be *cleaned*. The cleaning process is divided into two parts: first of all, those records which do not contain all the fields correctly filled must be erased, otherwise this missing or corrupt information will influence the final results and can lead to wrong conclusions; the second part will be focused on treatment of the terms themselves. For this purpose *Fuzzy Logic* and *Thesaurus* methods will be applied, in order to group elements of equal meaning.

The third step is the *Profile Generation*, which will be obtained analyzing the refined and cleaned database. The profile is based on two main concepts: the *Literature Profile and Research Community Profile* and *the State of the Research and its Evolution*. The first part provides information about the publications of the research field and the researches and practitioners involved in it. This information is based on simple text summarization through summary lists and different visualization elements such as co-occurrence maps, which are based on co-occurrence matrices (White and McCain 1998). These visualization elements will allow identifying synergies among different terms such as authors, countries or keywords.

The second part is centered on the technology as such and it is mainly based on two text mining methods: text summarization, with which the main concepts dominating the technology field will be detected by looking at the top keywords present in each year under study; and NLP which will be used to identify the dominating concepts (phrases) within the abstracts and titles of the publications. In addition to this, the usage of keywords throughout publications over time is performed, based on the study of trends to detect changes in keywords. This information makes it possible to present certain insights into emerging issues for the technology development over time. Furthermore, the trend in the number of publications related to a technology helps to comprehend its position in the technology life-cycle (Yoon et al. 2013).

4 Results: Big Data Technology Profile

The whole refinement process was performed aiming at retrieving only those papers which had the following characteristics: contained the term "big data" in the title; it was not a literature review or a technology application; computer science or mathematics category. The refined database contained 3064 records which were cleaned deleting duplications and corrupted fields, finally obtaining a database of 2244 records (57% Scopus, 43% WOS). Analyzing the literature profile, the publications are divided as follows by their nature: academic 70.69%; private company 16.89%; government organization 11.08%; and private research centers 1.35%. The evolution of each kind of publications is shown in the left graphic of Fig. 1, where it can be appreciated that the technology has surpassed the embryonic phase and has entered the growing phase, thus it can be said that it is still far from reaching the declining phase.

The type of publications can be separated into the following groups: conference papers 68.73%, articles 29.66% and book chapters 1.61%. It is worth identifying the trend of each type of publication, as it can be seen on the right graphic of Fig. 1, which tells us that initial contribution was mainly made by conference papers, as it is normal in a young growing technology, but the contribution of articles has gradually increased in the last years, indicative of the degree of maturity that the technology research is reaching.

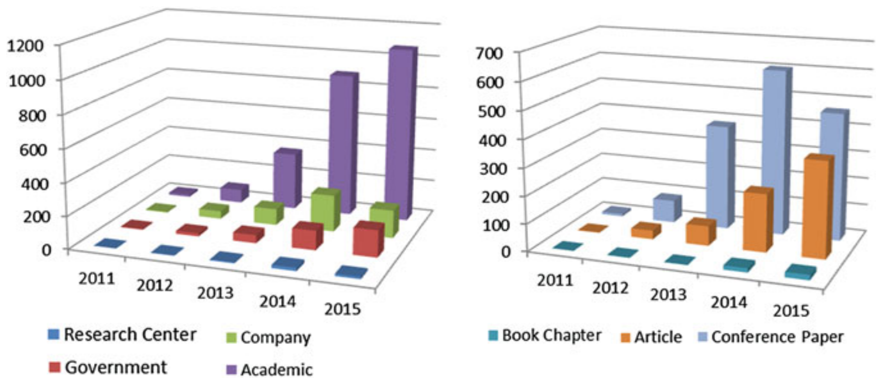

Fig. 1 Publication trend broken down by type of entity and publication type

Table 1 Big data leading research community

Country (#)	Organizations (#)	Authors (affiliation) (#)	Hot topics
U.S.A. (647)	International Business Machines Corp. (IBM) (39) Univ. of California (35) Microsoft Corporation (23)	Raghu Nambiar (Cisco System Inc) (5) Georgios B. Giannakis (University of Minnesota) (5) Meikel Poess (Oracle Corporation) (5)	Machine learning Data analytics Social media Data mining
China (544)	Chinese Academy of Sciences (85) Tsinghua University (50) Northeastern University (23)	Lizhe Wang (Chinese Academy of Science) (8) Wanchun Dou (Nanjing University) (6) Xiaofeng Meng (Renmin University) (4)	Data mining Rapid development Data storage Massive data
India (148)	VIT University (15) IBM India Pvt Ltd. (9)	M. Baby Nirmala (Holy Cross College) (4) Pethuru Raj (IBM India) (4)	Unstructured data Large amount Social network
Germany (120)	Karlsruhe Institute of Technology (8) Technical University Berlin(6)	Volker Markl (Technical University Berlin) (5) Peter Baumann (Jacobs University Bremen) (4)	Social media Business Intelligence Data analysis
South Korea (91)	Korea University(5) Sungkyunkwan Univ. (5)	Tai-Myung Chung (Sungkyunkwan University (3) Jang Haengjin (KISTI) (3)	Data mining Processing time Social network

The research community can be described by the leading countries and the leading authors and entities within each of them. In addition to this and based on the NLP technique, the hot topics for each country can be identified. Table 1 shows all this information, where there are some insights worth pointing out. There are several companies leading the field and this is not a common characteristic of the majority of the research fields. The reason for this is the immediate applicability of Big Data into companies and its impact in the efficiency of analytics and ultimately in revenues. In addition to this, it can be seen that there are slight differences among countries in terms of the hot topics, but in most of them, those topics related with data mining and social networks have raised interest among the researchers.

The research community and the state of the research can be linked with co-occurrence maps such as author-keyword maps. Figure 2 shows this information where the main sub-field of Big Data technology can be seen together with the principal authors involved in each of them. This information allows identifying who is leading each sub-field and allows discovering shared research interests which could give rise to future collaborations.

Keyword analysis and NLP applied to abstracts and titles allows a more exact identification of the main topics for each year. The analysis of the usage of the keywords throughout publications over time will describe the evolution of the technology. This analysis is shown in Table 2, which allows drawing some conclusions.

It is beyond doubt that Cloud Computing technology goes hand in hand with Big Data, as it appears within the most frequent keywords in all the years. In addition to

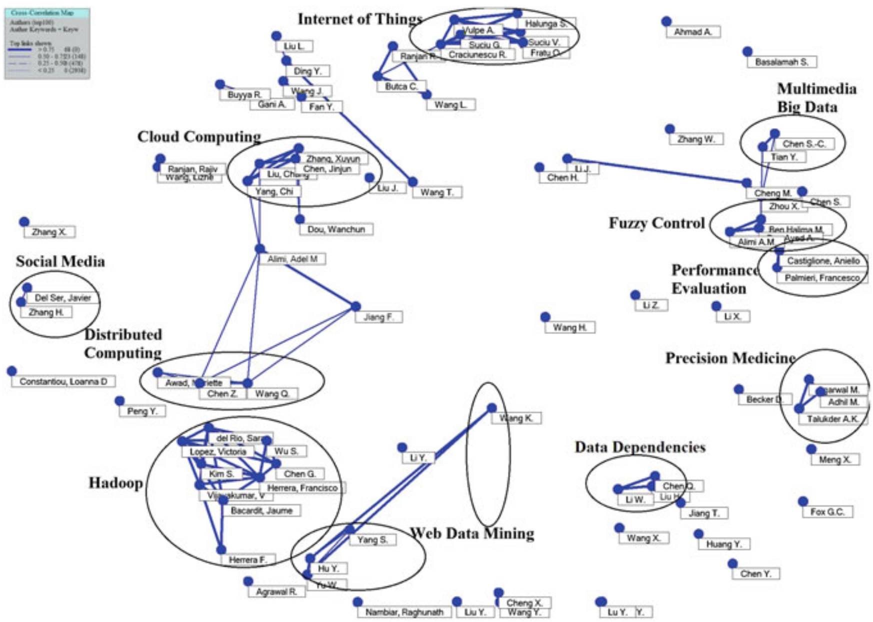

Fig. 2 Author-keyword co-occurrence map, 2015 year

Table 2 Top Keyword and NLP analysis resulting phrases

Top 2012		Top 2013		Top 2014		Top 2015	
Keywords	NLP	Keywords	NLP	Keywords	NLP	Keyword	NLP
Big data analytics	Big data analytics	Big data analytics	Big data analytics	Big data analytics	Big data analytics	Cloud computing	Big data analytics
MapReduce	Machine learning	Cloud computing	Data mining	Cloud computing	Big data application	Big data analytics	Big data application
Cloud computing	Big data era	Data mining	Big data application	Hadoop	Collect data	MapReduce	Data source
Data mining	Data mining	MapReduce	Real time	Data mining	Data mining	Data mining	Data mining
Hadoop	Social network	Machine learning	Social network	MapReduce	Unstructured data	Machine learning	Decision making

Table 3 Top increased keywords

Top 2012 (%)	Top 2013 (%)	Top 2014 (%)	Top 2015 (%)
Big data analytics (1000)	Privacy (1100)	Business intelligence (1000)	Data security (800)
MapReduce (700)	Clustering (900)	Social network (1000)	Spark (800)
Cloud computing (700)	Data integrity (800)	Data quality	Framework (700)
Data mining (400)	Database (700)	Clustering (800)	Scalability (700)
Hadoop (400)	Ontology (600)	Data warehouse (800)	Simulation (600)

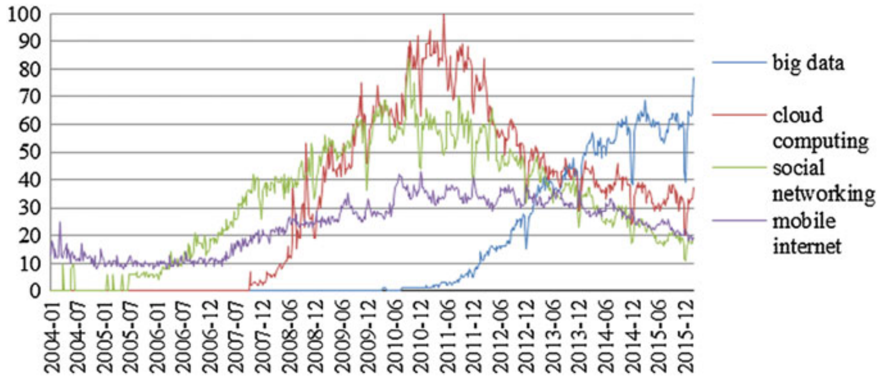

Fig. 3 "Big services era" technology enablers search tendencies. *Source* Google Trends (www.google.com/trends)

this, several methods are taking advantage of Big Data, such as Data Mining and Machine Learning, and they are continuously being analyzed in literature. Regarding to the most increased keywords, it can be seen in Table 3 that there are several topics increasing its usage, especially those related with the data itself, in terms of quality and integrity. The presence of *Spark*, an open source Big Data solution, gives us an indicative of the expansion that this technology is taking.

Regarding technology trends, there are some ideas worth mentioning. As it was mentioned, Big Data is generating the "Big services era" together with another three technologies. It is worth analyzing the evolution of the interest that these technologies are raising in terms of search queries, as it can be done with the *Google Trends* tool. Figure 3 shows how even if the other three technologies had their "popularity" peaks in 2010, Big Data is currently attracting more interest than ever, and data shows a likely increase in the years to come.

5 Conclusions and Future Work

In spite of having already generated a significant research community, Big Data is still raising interest among researchers and practitioners. There are many technologies and methods that are accompanying it on its way, either taking advantage of its functionalities or enhancing each other. Among others, many data analytics-related methods are being studied and improved, such as Data Mining, Machine Learning or Simulation processes. In addition to this, companies should be aware of its utility when it comes to analyze the social networking and as regards its applicability to Business Intelligence. Big Data is still facing some challenges in its evolution, such as data integrity and security, but it is likely that the growing research community is going to solve this and similar kind of problems in the years to come. Many other conclusions can be drawn, but this paper just aims being a starting point for those who have interest or need to be aware of Big Data evolution.

Future work will be based on taking advantage of all the information generated by the application of the described approach. As mentioned, the second phase will be centered on forecasting Big Data technology, besides generating a technological Roadmap in order to provide a complete picture of it. Focusing on what concerns to the improvements, the forecasting process will be enriched with Web Mining, applying NLP and Information Retrieval to Web page contents.

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Management, Innovation Capacity and Fear of Failure in a Sample of Spanish Firms

Antonio López Ramos, Carlos Rodriguez-Monroy and Félix Calvo-García

Abstract The management of error is considered a source of learning and its main barrier is the fear of failure that is present in all human beings and therefore influences in the activity of any organization, in its performance, in its capacity for innovation and in other related variables such as leadership and climate. Then the paper objective is to analyse through the behaviours of a sample of directors of Spanish companies the relationship among performance, fear of failure and the innovation capacity in accordance with the organizational assessment model proposed by Stuart-Kotze. The importance of this work is due to determines a new and a wider field of academic study and at the same time a lookout for managers to monitor the influence of fear of failure in their organizations.

Keywords Innovation · Management · Fear of failure · Psychological safety · Trust

1 Introduction

The objective of this study is to show the influence of fear of failure (FF) on the business activity. According to (Kotter 2001; Stuart-Kotze 2006) the company's activity is made up by two functions. The first one, which Kotter call management is the daily performance (DP), which includes every task related to production with the exception of changes and innovation proposals, which correspond to the second

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activity. To this second activity Kotter calls leadership. Also, the authors consider that transactional leaders are in charge of the (DP), whereas transformational leaders generate innovation. However, some authors consider that innovation not only depends on the transformational leadership, but also on the transactional leadership (Kahai et al. 2003).

About this literature also states that transformational leadership influences into performance through the climate (Sun et al. 2012). However, whereas the literature establishes a connection between transformational and transactional leadership, it does not estate a clear relation between transactional and transformational leadership styles. Finally, to make innovation possible, the first step is that the organization shows innovation initiatives. For this to happen is necessary at first, the developing of the innovation capacity (IC) in the business Van den Ven (1986).

According to all those assumptions, the first objective of this work aims at finding the way in that a climate of (FF) affects to (IC). This will establish a link between (FF), transformational leadership and innovation. Second objective is about identifying whether (FF) also affects to the efficiency in (DP). Finally, the third objective aims to find whether (FF) may be a moderator variable that establishes a link between (DP) and (IC). This will show whether transactional leadership relates to transformational leadership.

2 Innovation, Performance, Fear of Failure and Kotze Model

To test the causal relationships between the innovative capability of an organization, its daily performance and the influence of fear to failure, we performed a multivariate analysis of the responses of a sample of managers in completing the on line M-CPI questionnaire (Momentum Continuous Performance Indicator), developed by Stuart-Kotze (2006) and based on the assumptions described below. The questionnaire consists of 132 items, with a Likert (1932) response scale with 6 levels of response (0–5).

The optimum generation capacity of change initiatives (IC) of a team depends on the contribution of both managers and employees. For this to happen, in the first phase, a manager must create a proper environment of psychological safety and trust so that the team can show their talent and creativity (Lopez et al. 2015). Thus, Stuart-Kotze calls accelerating behaviours the ones that a manager exhibits in its role of leader to stimulate his team to challenge the status quo. These behaviours build a suitable environment, implementing the necessary processes to develop talent, strategic vision or continuous improvement and reserving a place on the agenda to generate change initiatives. The second phase of innovation is a process where these initiatives are subsequently implemented. When an innovation is implemented recurrently it becomes reflected in the DP, and runs independently of future change initiatives. Stuart-Kotze calls sustaining behaviours to those that ensure DP. Finally, Stuart-Kotze calls blocking behaviours those that generate pressure, demotivation, discomfort, frustration or stress. Those behaviours reduce the organization efficiency, facilitating the occurrence of errors and decreasing the quality of an appropriate environment for innovation. These behaviours are behaviours derived from fear of failure (Lopez et al. 2015).

The Stuart-Kotze model identifies those three categories of behaviours described through the M-CPI questionnaire. The questionnaire consists of 132 questions and is an individual self-assessment of the accelerating, sustaining and blocking behaviours shown in the workplace. This is a forced response questionnaire according to the Likert-type format (1932), where five points mean, "totally agree" and zero means, "strongly disagree".

3 Theoretical Approach and Assumptions

Transformational leadership motivates to a great extend climate in the workplace (Sun et al. 2012) stimulating employees' innovative initiatives, (Lee and Chang 2006). Because the FF influences climate and climate influences innovation raises the hypothesis that FF must bear some relation to innovation through climate as a moderator variable. This leads to the following hypothesis:

- H1. There is a positive relationship between FF and IC

Moreover, literature states that transformational leadership influences performance through climate (Sun et al. 2012) and besides, the climate influences the performance and innovation as well. So there must be a relationship between performance and innovation through climate as a moderator variable. To test this approach the following hypothesis is proposed:

- H2. There is a positive relationship between DP and IC

As with the initial model both scenarios resulting set forth in Fig. 1.

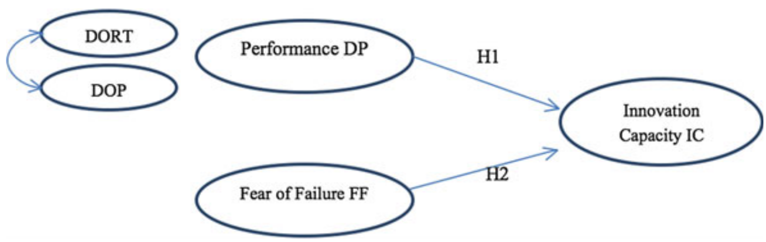

Fig. 1 Initial model

4 Methodology

To contrast the causal relationships between daily performance DP, the influence of the behaviours associated to FF and the innovative capacity IC in an organization, it has been performed an analysis of the covariance structure of the data obtained from a sample of Spanish executives Table 1, through the completion of the M-CPI questionnaire developed by Stuart-Kotze. The scope of our study is limited to the Spanish territory and with respect to the sample size they looked for a number around 300 individuals according to exploratory factor analysis (Muthén and Muthén 2002). The required feature was that managers have co-workers. Regarding the degree of participation, from a sample of 350 managers contacted, a total of 286 questionnaires were suitable for the project.

The verification of the hypotheses for this research was carried out by structural equation modelling, (SEM). For data analysis the two-step procedure recommended by Anderson and Gerbing (1988) was followed. In the first stage, to assess the psychometric properties of the measurement model, we conducted a confirmatory factorial analysis (CFA) of second order to check the properties of the items and select a set of homogeneous items. Secondly, the proposed structural relationships between the latent variables were added and analysed by Structural Equation System. IBM SPSS statistical software IBM SPSS-AMOS V.20 was used in both cases, using the Method of Maximum Likelihood (ML) with the statistical correction proposed by Satorra and Bentler (1994).

Table 1 Covariance structure of the data obtained from a sample of Spanish executives

Firms	Size	Nationality	Activity	Firms	Size	Nationality	Activity
2	Middle	National	Construction	3	Large	National	Services
1	Small	National	Construction	2	Small	National	Services
2	Small	National	Consultancy	1	Large	Foreign Multin.	Services
1	Middle	National	Financial services	1	Large	Spanish Multin.	Services
1	Large	National	Telecom services				

5 Results

In order to verify if the sample can be considered homogeneous, statistical tests of comparison of means for independent samples (Leneve test and t-tests) were performed. As a result, the samples are statistically homogeneous for each of the constructs. So it is assumed equal variances.

The measurement model initially proposed envisaged 132 items or behaviours: Accelerating (48) Sustaining (48), Blocking (36). Through the AFC some items with low loads or high residuals were detected so that they were eliminated, leaving finally a model consisting of 28 observable variables and 3 latent constructs. All indexes of variance of each construct exceeded the minimum acceptable value of 0.50 (Bagozzi and Yi 1988; Fornell and Larcker 1981), so that in the first construct (innovation capacity-IC) 12 variables load, in the construct 2 (Performance-DP) 11 variables load and lastly in the construct 3 (Fear of Error—FF 5 variables load, ($p < 0.05$). Factorial analysis of the behaviours that drive the IC shows a sample adequacy of 0.951 of KMO index Kaiser-Meyer-Olkin, considered acceptable. Similarly, the KMO of the factorial analysis of the performance-oriented behaviours is 0.927 and the one corresponding to the behaviour associated with FF is 0.8. Also, the reliability of the constructs of the model determined by Cronbach is 0.938 for the construct IC, 0.927, for the construct DP and 0.871 for the construct FF. The internal consistency of the constructs is proved in all cases thanks to Cronbach's alpha values, which exceed the minimum acceptable value of 0.70 (Nunnally and Bernstein 1994). Also, all the items that make up the factorial matrix of the constructs exceed the reference value of 0.60 (Bagozzi and Yi 1988). According to the above results it is possible to validate the measurement model, as the convergent validity is verified by the fact that all standardized factorial loads are significant and greater than or equal to 0.7. And in turn, the discriminant validity is also verified because all correlations between a pair of latent variables are less than the square root of the variance extracted from the variable. See Table 2.

The exploratory factorial analysis shows that the sample perceived DP through two constructs (Fig. 1): DOP, (management oriented to planning, procedures and situational analysis), and DORT (management oriented to daily task), see Table 3. This means that planning and task are perceived as two separated activities.

Table 2 Scales validity by construct

Construct	AFC, AVE, α y % factorial load	Correlations IC DP FF
Innovation capacity IC	$\chi 2$ = 144.050 df = 52 RMSEA = 0.078 CFI = 0.96 TLI = 0.949 AVE = 56.503 α = 0.938 %factorial load = 0.803	0.896
Performance (DOP) (DORT)	$\chi 2$ = 496.555 df = 151 RMSEA = 0.05 CFI = 0.960 TLI = 0.957 AVE = 56.696 α = 0.927 = 0.782	0.573 0.884
Fear of failure FF	$\chi 2$ = 8.170 df = 3 RMSEA = 0.077 CFI = 0.993 TLI = 0.978 AVE = 58.302 α = 0.871 %factorial load = 0.712	0.729 0.609 0.808

Table 3 Final model behaviors

IC	I try that people be recognized by their results
IC	I'm responsible for both good and bad team performance
IC	I present my proposals convincingly
IC	I eliminate obstacles to get things done
IC	I always act visibly
IC	Once someone accepts its task responsibilities, I don't interfere
IC	I evaluate actions based on their long-term effects
IC	I listen and ask others for their opinions
IC	I try to identify who can count and when
IC	I make people be part of an integrated system
IC	I manage by exception, letting the system take care of the daily affairs
IC	I'm always willing to make hard decisions
FF	Sometimes I get so frustrated trying to get the goals that give up
FF	I express my displeasure ignoring people
FF	I often say to agree with a decision, when I'm not
FF	I get angry when I get frustrated
FF	I get angry with people when they make mistakes
DORT	I pay attention to details
DORT	I try to help people to understand their objectives clearly
DORT	I am loyal to my teammates and support them
DORT	I am accessible to people
DORT	I am patient with people when they make mistakes
DORT	I put the strategy in terms of goals to the team
DORT	I try to observe processes and procedures
DORT	I make sure people know exactly how it will measure its performance
DORT	I try the people feel at work like in family
DORT	I set priorities and I focus on them
DORT	I develop systems and processes that deal with the daily task

Besides, according to the resulting structural equation model, Fig. 2, FF is negatively correlated with the construct DP. Also, it seems obvious that the greater the presence of FF, the less open the communication and the greater the difficulty in learning from mistakes, which is what facilitates their repetition which negatively influences organizational efficiency. The negative correlation between FF, climate and DP is fully in line with literature on this subject. Along the same lines, SEM corroborates our first hypothesis about the causal relationship between FF and IC (see Fig. 2). Finally with respect to the second hypothesis, SEM confirms the existence of a causal relationship between DP and IC.

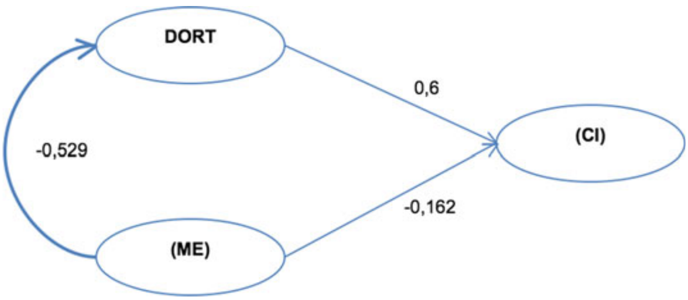

Fig. 2 Final model

6 Discussion and Conclusions

The non-inclusion of DOP in the DP structure, leads us to consider a new hypothesis for future research. It is possible that this lack of planning in DP is the cause of management by putting out fires, something common in many Spanish companies. Since our outcomes indicate that the problem is not the lack of planning but a question of not being aware that strategic planning should be related with the daily tasks, DP. In fact, in the SEM the DOP construct is excluded from the model. May be a reason for that is the fact that in large organizations the larger the number of managers make decisions, the greater the chance for conflict. So, there is a negative interaction between planning and decentralized organizations (Andersen 2004). To explain outcomes it could be that, in order to avoid the appearance of conflicts the sample of companies under study does not pay so much attention to planning. Also, the negative correlation among FF, climate and DP is fully consistent with the literature.

The corroboration of the first hypothesis, that is the existence of causal link between FF and IC, is consistent with the literature because of the behaviours associated with FF have a negative impact on the climate. This means a lack of transformational leadership, the leadership style that boost the climate (Sun et al. 2012) and drives innovation and change, (Lee and Chang 2006). With regard to the confirmation of the second hypothesis, the outcomes show that it seems that the sample accelerating behaviours tend more toward building an integrated system, with suitable processes and consistent with a strategic vision, that push teams to challenge the status quo. Although the structure of the Stuart-Kotze model has not allowed establishing any causal relationship between the action orientation in DP and the system orientation IC, it seems that the sample could be doing two things:

On the one hand, they use their accelerating behaviours, initiative, coordination and development of processes to establish, in accordance with the strategic vision, improvements in the system, integrating activities across the organization, in order to prevent errors in performing DP. This hypothesis would explain the correlation between FF and DP, where FF motivates preventing errors in order to assurance the efficiency in DP, which in turn drives IC. That is, the performance efficiency motivates change. The improvements implementation would be a responsibility delegated to employees, but without taking into account their own initiatives, because that could increase the likelihood of errors out of the management control. In this way, change is always a management decision.

However, the lack of behaviours aimed at promoting employee initiative, as a part of the set of accelerating behaviours, suggests that the purpose of the accelerating behaviours of our sample is merely to create a good climate in order to ensure efficiency in DP and even for instance to ensure the good results of the organizational climate assessment. This means that a good climate that benefits both good efficiency in DP and enables IC is only used to ensure DP, while retaining the benefit of accelerating behaviours that promote IC, as a latent potential. One possible explanation that would require further analysis is that the lack of change initiatives depends not only on the organizational climate of companies in our sample, but the allocation of time in the day-to-day running of the company, thus lacking an opportunity for the employees to express their initiatives. Furthermore, this latent potential will be even more eroded, with the passing of time, due to the employees demotivation at having been excluded from the whole innovation process.

Even though the limitation of our sample prevents us from extrapolating the outcomes to all Spanish business organizations, the outcomes are a source of information for managers who can monitor whether the presence of narcissistic behaviours are affecting their organizations. The importance of reducing the FF in managers is evident from the benefits that can result in the organizations: improving teamwork and transformational leadership, with their corresponding impact on the IC of the organizations, which is the release of innovative potential, due to the employees participation in the whole innovation process and besides the contribution to the daily performance, climate and error prevention management which enhances the intellectual capital of the company.

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Sustainability Assessment of Environmentally Conscious Manufacturing Companies

S. Ozmehmet Tasan, B. Felekoglu and E. Ozmehmet

Abstract Sustainable manufacturing is becoming increasingly important with substantial social, environmental and economic benefits, thus companies show more tendency to adopt this concept. Recognizing the benefits of sustainability, manufacturing companies need to measure how sustainable they perform. However, sustainability can be thought as an abstract issue which is difficult to measure and also assess. Measuring sustainability is a continuously evolving research area which generates various sustainability indicators to assess companies' production activities. Practically, while evaluating the sustainability performance of a manufacturing system, various indicators should be considered simultaneously. This study focuses on the usage of sustainability indicators to assess the sustainability of a production company from a multi-criteria decision making point of view. As a case study, the sustainability performances of an international beverage company which produces non-alcoholic drinks were evaluated. TOPSIS method was adopted as an assessment method with the use of several conflicting indicators simultaneously.

Keywords Sustainability indicators · Sustainable manufacturing · Multi-criteria decision analysis

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1 Introduction

The interest to manufacturing in a sustainable way has increased in industry as the companies started to realize the substantial social, environmental and economic benefits of producing their products in a more sustainable way. From manufacturing perspective, *sustainability* can be defined as diminishing the negative effects of manufacturing operations on the triple constraints of sustainability i.e. people, planet and profit, simultaneously. Manufacturing actions considering the environmental issues contribute to the firms for gaining competitive advantage in the market. Because the actions concern the environment includes typically the product and process focus which are useful to derive value improvement and cost decline (Wiktorsson et al. 2008). Additionally, the firms considering the social issues such as health and welfare of their workers and stakeholders gain similar strategic advantages.

Sustainability indicators are developed with the same sense of financial indicators and utilized to measure the success of the company in terms of sustainability and sustainable manufacturing (Veleva and Ellenbecker 2001). Despite the vagueness of the sustainability concept, indicators serve to monitor and assess social, environmental and economic impacts of manufacturing activities (Warhust 2002).

This study proposes the usage of Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to assess manufacturing sustainability by using several conflicting indicators simultaneously. The structure of the study is as follows: section two provides better understanding regarding the terms sustainability and sustainability indicators. Section three covers TOPSIS method as a sustainability assessment methodology. Section four presents the case study in an international beverage company which produces non-alcoholic drinks. Finally, the findings are discussed and concluded in section five.

2 Sustainable Manufacturing

The concept of *sustainability* and *sustainable development* was first mentioned in the report of World Commission on Environment and Development (WCED) (United Nations 1983, 1987). The report indicates that additional efforts for increasing the environmental investments will provide sustainable development. Since the fundamental objective is to sustain human life and keep planet in a way that every generation can live, sustainable development is the main concern in the concept of sustainability. WCED, known as the Brundtland Commission of United Nations, defined sustainability and sustainable development as “the development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (United Nations 1987). WCED also depicted that sustainable development is not a definite concept that promise achieving a fixed state; it is the process that rely on environmental, social and economic aspects.

Sustainable development concept has been stimulating interest in many research and application areas. Among these areas, the focus of this study is manufacturing. With sustainable manufacturing, companies aim to increase their operational efficiency, reduce their waste while respecting environment and align their operations with social, environmental and economic regulations. By this way, companies can achieve potential benefits of sustainable manufacturing such as increasing competitive advantage, reaching new customers, building public trust, strengthening their reputation, improving health and welfare of their stakeholders.

Recognizing the benefits of sustainability, manufacturing companies need to assess how sustainable they operate using performance measures which are called sustainability indicators.

When the literature on sustainable manufacturing reviewed, it can be seen that most of the research focused on developing sustainability indicators (OECD, n.d.; Rennings and Wiggering 1997; Krajnc and Glavic 2003; Raizer-Neto et al. 2006; Joung et al. 2013). Among these studies OECD (n.d.) gives a list of sustainability indicators some of which are related to manufacturing and can be used for evaluating the sustainability of manufacturing operations. Rennings and Wiggering (1997) investigated the linkage between environmental and economic aspects of sustainability indicators which shows promising potential for assessing sustainable manufacturing. Krajnc and Glavic (2003) categorized production indicators into three, namely social, environmental and economic. Environmental indicators were classified as input and output, whereas economic indicators were classified as financial and employee related. Besides, indicators to measure sustainability in industrial manufacturing were grouped under product, operation and management areas in Raizer-Neto et al.'s (2006) study. One of the most comprehensive categorizations of sustainable manufacturing indicators were given in Joung et al.'s (2013) study. They identified five dimensions of sustainability in assessing company's manufacturing operations. These dimensions are formed from environmental, economic, social, technological and performance points of view.

In the light of this literature review, it can be stated that various sustainability indicators related to manufacturing operations exist. In this study, we will be using a combination of various sustainability indicators and consider them simultaneously while evaluating the sustainability performance of manufacturing operations.

3 Sustainability Assessment Methodology: TOPSIS

There are numbers of tools and techniques for assessing sustainability. A comprehensive review of these methods can be found in Ness et al. (2007) study. They categorized these methods into indicators and indices, product related assessment and integrated assessment.

In this study, manufacturing related sustainability indicators, which conflicts with each other, are used. Due to the conflicting nature of these indicators, assessment using simple calculation methods becomes useless and inefficient. To overcome this issue, an integrated assessment method, i.e. TOPSIS method, has been used as a multi-criteria decision analysis method. In multi-criteria decision making problems, the purpose is not optimizing the solution. In these problems, criteria are evaluated simultaneously in order to find the compromise solution. The criteria and its outcome must be measurable and valid for every alternative decision.

TOPSIS was developed by Hwang and Yoon (1981). The idea behind the method is that the chosen alternative is expected to have the shortest Euclidean distance from the ideal solution and contrarily have the farthest distance from the negative ideal solution. The ideal solution is hypothetical solution that corresponds to maximum attribute of all attribute values in database where comprising the satisfying solution. In this sense, the negative ideal solution is hypothetical solution as a consequence that all attribute values correspond to minimum attribute values in database (Rao 2007). Thereby TOPSIS gives the closest solution to the hypothetically best and also which is farthest from the hypothetically worst.

TOPSIS can be summarized in six steps. In the first step, the evaluation matrix is constructed using listing alternatives horizontally and criteria vertically. In the second step, the center values in the evaluation matrix are non-dimensionalized by dividing each center value by the norm of the total outcome vector. In the third step, relative importance is calculated by multiplying the matrix values by normalized weights of each criterion. In the fourth step, positive and negative ideal solutions, which are the set of best or maximum/worst or minimum values of each criterion respectively in the evaluation matrix, are found. In the fifth step, the Euclidean distances are calculated using the separation of each matrix value from the ideal solutions. In the last step, overall or composite performance score of each alternative is calculated in terms of relative closeness to the ideal solution.

4 Case Study

In the case study, we gathered the sustainability related data from an international beverage company which produces non-alcoholic drinks. The company has operations in Turkey, Pakistan, Kazakhstan, Azerbaijan, Kyrgyzstan, Turkmenistan, Jordan, Iraq, Syria and Tajikistan, and it is headquartered in Turkey. Data considered in this case study used for assessing the sustainability of factories in Turkey, Kazakhstan, Jordan and Azerbaijan are shown in Table 1.

It is not possible to conduct a study for Azerbaijan since data regarding its manufacturing activities are not available on reports. However, information provided for the years of 2011 enables TOPSIS method to compare those countries in terms of indicators represented in Table 2. The year of 2011 is chosen in order to

Table 1 Data gathered for 2011 provided by factory reports from four countries

	Turkey	Jordan	Kazakhstan	Azerbaijan
Water use ratio (L/L)	1.42	2	1.7	1.74
Water use amount (m^3)	3,850,537	137,847	510,591	306,059
Energy use ratio (MJ/L)	0.255	0.455	0.333	0,222
Total energy use from primary resources (mil.mj)	301.21	12.55	59.55	11.59
Solid waste ratio (g/L)	3.38	11.19	2.69	1.16
Recycling ratio (%)	94.95	88.9	85.34	92.47
CO_2 emission ratio (g/L)	30.1	56.03	49.46	49.44
Total shipping emissions (g/L)	15.57	21.46	7.17	13.53
Combustible use ratio for shipping (L/KL)	5.67	6.81	2.61	5.21
Sales volume (million unit box)	546.8	12.9	70.5	42.3
Total working hour	9,405,144	915,899	1,231,340	929,920
Total number of employees	2820	368	599	269

Table 2 Sustainability indicators and their meanings

Sustainability indicator		Definition
$I_{1,1}$	Water use ratio (L/L)	Water used per produced amount of liter
$I_{1,3}$	Specific water consumption (million m^3/million unit box)	Water use amount/sales volume
$I_{1,5}$	Energy use ratio (MJ/L)	Energy used per produced amount of liter
$I_{1,5}$	Specific energy consumption (million MJ/million unit box)	Energy use amount/sales volume
$I_{1,7}$	Solid waste ratio (g/L)	Solid waste per liter produced
$I_{1,9}$	Recycling ratio (%)	Absolute value
$I_{1,10}$	CO_2 emission ratio (g/L)	CO_2 emission per liter produced
$I_{1,11}$	Total shipping emission ratio (g/L)	Absolute value
$I_{1,12}$	Combustible use ratio for shipping (L/KL)	Combustible used/produced amount of liter
$I_{5,1}$	Sales volume per working hour for an employee (million unit box/h)	Total working hour per employee/Sales volume

apply TOPSIS method because the data is provided completely for those countries where the consistent analysis is possible considering the designated indicators. In addition to existing product indicators, a new indicator is included in the analysis. Differently from the previous analyses, new indicator appertains to the group of social indicators. These indicators are specified as *I*.

The sustainability indicators are calculated and the evaluation matrix is formed as shown in Table 3. Indicators indicating the values of absolutes mass are assigned relatively small weights since the records related to those value can change the

Table 3 Evaluation matrix

	$I_{1,1}$	$I_{1,3}$	$I_{1,4}$	$I_{1,5}$	$I_{1,7}$	$I_{1,9}$	$I_{1,10}$	$I_{1,11}$	$I_{1,12}$	$I_{5,1}$
Turkey	1.42	0.00704	0.255	0.55086	3.38	94.95	30.1	15.57	5.67	0.16395
Jordan	2	0.01069	0.455	0.97287	11.19	88.9	56.03	21.46	6.81	0.00518
Kazakhstan	1.7	0.00724	0.333	0.84468	2.69	85.34	49.46	7.17	2.61	0.0343
Azerbaijan	1.74	0.00724	0.222	0.274	1.16	92.47	49.44	13.53	5.21	0.01224

Table 4 Performance values of countries

Countries	$C_{i,j}$
Turkey: $C_{5,1}$	0.42806
Jordan: $C_{5,2}$	0.46546
Kazakhstan: $C_{5,3}$	0.68918
Azerbaijan: $C_{5,4}$	0.80482

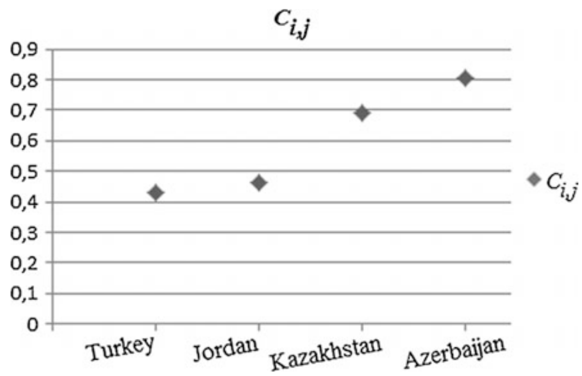

Fig. 1 Performance values for Turkey, Jordan, Kazakhstan and Azerbaijan at 2011

capacity of the plant. As a result of the TOPSIS method, performance values obtained are shown in Table 4.

It is clearly seen from Fig. 1 that Azerbaijan had better performance at 2011 amongst other countries. Turkey and Jordan share almost the same scores despite the differences of data.

While Turkey and Jordan performs nearly the similar results, Kazakhstan is positioned almost in the middle of the point between Jordan and Azerbaijan where Azerbaijan stands as a best performed country.

Detailed examination of the evaluation matrix can clarify this situation. Azerbaijan and Jordan have similar records according to production activities. Nevertheless, Jordan has higher values where the data is expected to be at the lower levels. Figure 2 illustrates the radar graph which provides better understanding for this statement.

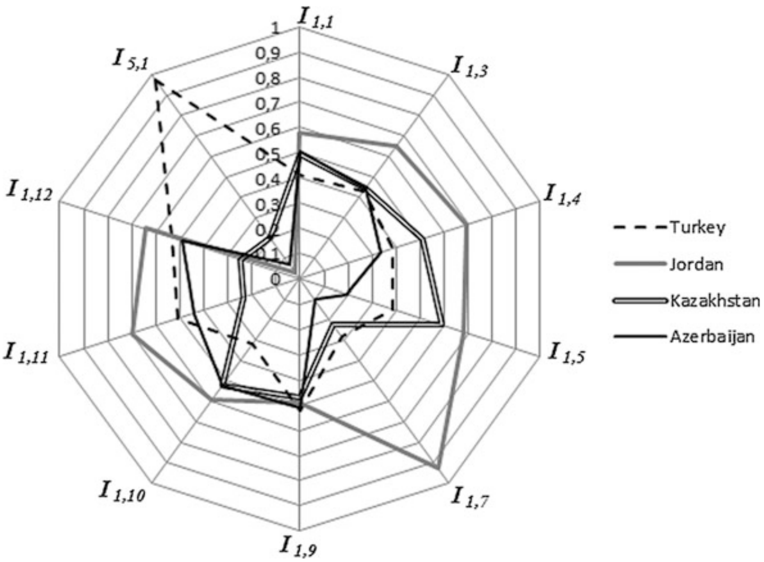

Fig. 2 Radar graph representation of evaluation matrix

5 Conclusion

As the world has become global, environmental problems due to manufacturing activities have become global problems too. The concept of using resources without utmost consuming them and manufacturing without harming the environment as much as possible led the term sustainability and sustainable development to emerge. Beside economic pressure and consumption of resources, manufacturers have been facing increasing costs and need for creating added value for customers. As a result of these circumstances, manufacturers started to adopt the concept of sustainability and recently, the interest of sustainable manufacturing has increased more than ever. The need to evaluate the success of adopting the concept of sustainability and assess its impacts from social, environmental and economic perspectives provide manufacturers with the realization of various benefits.

In this study, a multi-criteria decision making method, TOPSIS, is adopted in a real life case study to assess the manufacturing sustainability of an international beverage company which produces non-alcoholic drinks, using various conflicting sustainability indicators simultaneously. The method used has several advantages such as the application practicability and simplicity. Although a large number of indictors exist in the literature, in this study a limited number of them were adopted as the existing data collected by the company is restricted.

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Application of Innovation Management Techniques in SMEs: A Process Based Method

J.I. Igartua and L. Markuerkiaga

Abstract Small and medium-sized enterprises (SMEs) are facing harsh market conditions that threat their survival, what has increased their awareness that business as usual is no longer sufficient and that their future depends on their ability to offer innovative products and services, innovate and improve their value propositions and associated business models. Changing market conditions thus force smaller firms to adapt or reinvent their business through new technologies or unique value propositions. At the same time, a major liability of SMEs is that small firms lack the required resources, knowledge and technical capabilities to develop structured innovation processes based on innovation management techniques and tools (IMTs), and therefore one main challenge refers to SMEs capability to innovate. A process based method ch for innovation based on IMTs is presented in this paper. Precisely, this paper explains the processes, tools and outcomes of the application of this process based innovation method in several small SMEs, as long as the lessons learned and proposals for SMEs approaching this challenge.

Keywords Innovation · Innovation management · SMEs · Innovation management techniques · IMTs

1 Introduction

In the last decades, several factors have contributed to raise the concern over the ability of SMEs to offer innovative products and services, innovative business models, or their capability to innovate their business processes; in an over and over more turbulent environment. The European Commission and other actors (Milea

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et al. 2014) are concerned about the fact that few innovative EU SMEs grow into large, globally successful companies, stressing the need for SMEs to adopt a broader concept of innovation in products and services which includes any change that speeds up and improves the way businesses are conceived, developed, produced and marketed for new products and services.

There is a need for the European Commission (European Commission 2008a) to foster the innovation performance of micro-enterprises, through the mastering of innovation management, the implementation of integrated innovation frameworks and promotion of skills for innovation and competitiveness, with special attention to small enterprises. For SMEs managing the entire innovation process, from new idea to launch; requires a clear innovation strategy, an organizational culture that supports innovation, and innovation activities that ensure that the right ideas are developed efficiently.

However, superior and systematic innovation management is currently not established in the average European SME. According to European Commission (European Commission 2008b), SMEs have trouble formulating their needs in Innovation Management, which makes it difficult for any institution or agent to effectively support them. Besides, some other SMEs with a higher degree of awareness of Innovation Management see four major needs that are so far unmet: (1) the need to understand the business impact of Innovation Management, (2) keep their strategic positioning in mind while eliminating operational shortcomings, (3) build cross-border networks; and (4) accelerate the commercialization of ideas.

Moreover, according to European Commission (European Commission 2008a) companies do not use or master the existing set of innovation management tools (IMTs) relying in a short set, that usually are not embedded in the SME's organization although they may have practiced some of them with the help of consultants. This situation along with the missing rationality for selecting tools and techniques (IMTs) is unsatisfactory for SMEs. To cope with this situation, it is necessary to foster the understanding of tools and techniques in an integrated and well-structured model for Innovation Management, proving their impact on performance.

Therefore, both enterprises and individuals need to increase their innovation management capabilities and skills to improve their competitiveness. In this context, The proposed method in this paper focuses on the improvement of those capabilities on innovation and innovation management in SMEs, developing a real learning by doing experience in nine companies.

2 Innovation Process and Innovation Management Techniques (IMTs)

The need to manage the innovation process and context, demands that managers make effective and timely decisions based on multiple functions, inputs and disciplines (Brown 1997); and therefore, management tools and techniques are needed to support these complex decisions (Phaal et al. 2006) define a management tool as "a document, framework, procedure, system or method that enables a company to achieve or clarify an objective" (p. 418).

Innovation processes are defined and published by different authors (Tidd and Bessant 2009), but SMES struggle to implement them while developing experiences that will assure the absorption of that knowledge.

Thus, innovation processes need a clear defined innovation strategy, along with an innovative organization capable of running the innovation process by itself (Fig. 1).

Within this sequence of activities Innovation management techniques (IMTs) play a key role. Thus IMTs can be defined as the range of tools, techniques and methodologies intended to support the process of innovation and help companies to meet new market challenges in a systematic way (Igartua et al. 2010). Hidalgo and Albors (Hidalgo and Albors 2008) as well other researchers (D'Alvano and Hidalgo 2012; Lichtenthaler 2011) argue that IMTs are critical to increasing competitiveness, showing that proper application of IMTs facilitates a company's ability to introduce appropriate new technologies in products or processes, as well as the necessary changes to the organization.

However, and despite the importance for the scientific agenda of the research on innovation and IMTs, there is a need for companies to pragmatically apply the existing knowledge in innovation processes and IMTs in an affordable and efficient way (Cetindamar et al. 2012). How innovation processes can be applied, and the

Fig. 1 Simplified model of the innovation process (Bessant and Tidd 2011)

supporting role IMTs play are fundamental questions for SMEs, researchers and practitioners in order to assure valuable transfer of knowledge along the chain and the build of bridges between researchers and practitioners.

3 Applying of Innovation Management Techniques in SMEs: The InnoSMEs Method

There are many frameworks, models and maps showing how innovation processes occur and/or should be developed and put into practice (Tidd 2001), however SMEs need more objective orientated managerial methods, based on procedures, techniques and tools that will assure the transformation of inputs in outputs (Shehabuddeen et al. 1999). In this paper, the InnoSMEs method will be presented (see Fig. 2). This method is an innovation process method based on IMTs and tailored to fit SMEs shortages, needs and challenges.

The idea of developing this method is justified based on the need to give SMEs support on the management of innovation, according to advices regarding the need to promote skills for innovation and competitiveness, with special attention to small enterprises (European Commission 2008a).

The method apart from specified innovation results in SMEs through structured activities and IMTs, aims to update and upgrade participating companies' competences and skills on innovation management, developing their innovation management operational and strategic capabilities. Thus, the method stablishes a

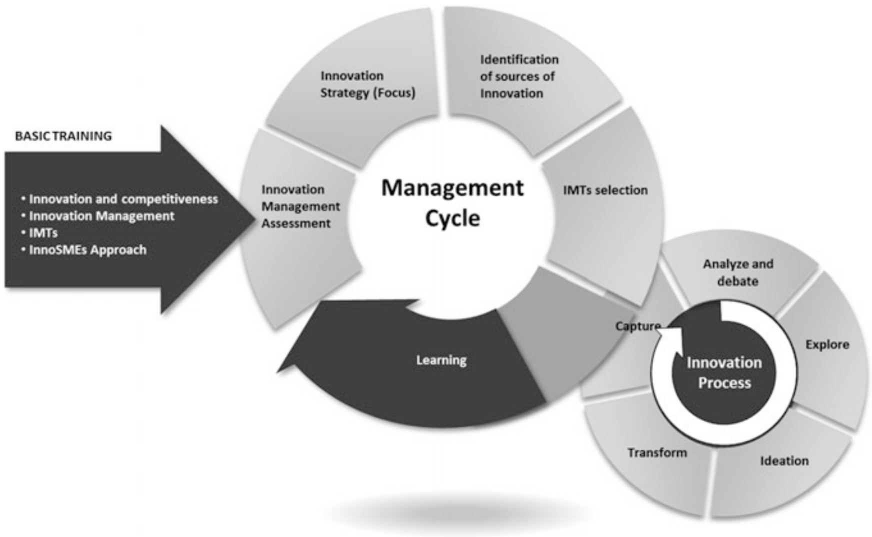

Fig. 2 Application of innovation management techniques in SMEs: InnoSMEs

collaborative university-industry support scheme (Pavlin 2016) that assures the development of innovation management capabilities in SMEs. These activities are designed to be performed by external support organizations and are defined to assure the absorption of innovation management skills and capabilities by SMEs, and therefore the learning process needed to support the entire method, and assure the future autonomy of the organization in their path towards innovation management.

Based on this grounds, the proposed method stablishes five phases aligned with the simplified model of the innovation process (Fig. 1), as well as other management activities in order to assure the correct running of the innovation process itself (see Fig. 2).

3.1 Management Cycle

To properly run the method a management process of six activities were developed (in an ongoing cycle):

- Basic training: SMEs awareness about innovation is fostered, as well as basic concepts about innovation, innovation strategies, innovation management, innovation processes as well as IMTs.
- Innovation management assessment: SME assesses its innovation management capabilities and approaches.
- Innovation Strategy: SME defines the aim of innovation in their company as well as the expected outcomes of the innovation process.
- Identification of sources of innovation: Based on previously defined strategy SMEs identify sources for innovation and information, establishing the bases for the implementation of a competitive intelligence system (CIS) (Tang and Li 2010).
- IMTs selection: Besides the CIS, other tools are reviewed and finally selected to support the innovation process, based on the innovation strategy.
- Learning: This activity evaluates the outcomes of the innovation process and through an assessment of the innovation process, stablishes lessons learned for the company.

3.2 Innovation Process Cycle

On the other in order to perform the innovation process five activities were performed in a sequence based on IMTs:

- Analyse and debate; what involves arguing about the innovation strategy of the company, their actual products and services, new technology and market trends, innovation focus and types of innovations, etc.
- Explore; what involves establishing a competitive intelligence (CI) system (based on free software) entitled to identify sources of innovation for the SME (Olszak 2014). Introducing CI in SMEs is a challenge, and different skills have to be coordinated within the enterprise and functions (Bartes 2013).
- Ideation; involves the creative process of generating, developing, and communicating new innovation ideas, where an idea is understood as a basic element of thought that once analysed and selected will need to be developed and transformed into a value proposition (Calvey 2011).
- Transform; involves designing and developing the value proposal what involves understanding the market, the potential clients' needs, and defining the innovative value proposal for them (Lindič and da Silva 2011).
- Capture; involves the design, development and test of the business model and the value proposition (Golnam et al. 2014).

4 Results

The proposed method has been tested through the development of two projects (MicroPIL and KIT-VPD) aimed to experiment the method in SMEs. MicroPIL project was focused to develop innovation in SMEs based on business diversification (Omar et al. 2015), while KIT-VPD focused on innovations in the value proposition (Osterwalder et al. 2014) of SMEs. Twelve SMEs participate in those two projects.

Both projects developed provide a novel method towards the implementation of innovation processes in SMEs and the enhancement of innovation management capabilities in SMEs in a collaborative university-industry lifelong learning experience.

The contribution for participating companies refer to the capabilities and knowledge absorbed by SMEs regarding the implementation of an innovation process, and the skills acquired in the use of innovation management techniques and tools—IMTs (Igartua et al. 2010).

About the innovation results achieved through this process, participant companies got some interesting outcomes in number of ideas, new sectors analysed, value propositions, and sources of innovation detected (Table 1).

Table 1 Results

	Total
Assessments	12
Customers segments identified	34
Ideas	75
Value propositions developed	19
Minimum viable products defined	11
Business models defined	15
Potential clients visited	26
Possible alliances with suppliers	21
Universities and technological centres contacted	12
Professional associations contacted	15

5 Conclusions

Small and medium-sized enterprises (SMEs) need to innovate and master innovation management through the implementation of integrated innovation frameworks, IMTs and promotion of skills for innovation and competitiveness. Both enterprises and individuals need to increase their innovation management capabilities and skills to improve their competitiveness. In this context, the proposed method focuses on the improvement of those capabilities on innovation and innovation management in SMEs, developing a real learning by doing innovation process experience based on IMTs in companies.

In the present study, the method was presented as an innovative method to explore and exploit the innovation process in SMEs. The results have been successful both for participants and university, due to its practical nature and the university-industry collaboration scheme developed. The results obtained show the great commitment of participating companies, as well as the fact than ten out of twelve companies continue with the ongoing improvement of the innovation management process implemented by their own.

We consider that this experienced and its components and results in terms of processes, tools, and outcomes, show a practical method ch to foster innovation performance in SMEs through the mastering of innovation management, the implementation of integrated innovation frameworks and promotion of skills for innovation and competitiveness.

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Assessing an Incubator Model in a Technological Centre: The Importance of the Spin-Off's Origin

Antonio González and Mikel Arcelus

Abstract This paper proposes an assessment framework for a university incubator using eight criteria. This framework has been used with eight high-tech spin-offs incubated in CEIT (Spanish Technological Centre that was created by the University of Navarra), taken into account the point of view of their CEOs with interviews and a questionnaire. The results achieved can provide some useful indications to managers of University Business Incubators (UBIs). The incubator's services demanded by the spin-off depend on several parameters, but the promoter profile of the new firm (a single person or the university itself) is a critical parameter.

Keywords Entrepreneurship · Academic spin-off · University incubator · Incubation mechanisms

1 Introduction

The social mission of a technological centre is to transfer latest technology to society, and the role of its incubator is focused on the same aim (Mian 1996), enhancing and promoting creation of new high-tech firms.

The advantages of a close proximity to a university for these new ventures are clearly recognized in the literature (Arrow 1962), but the assessment of the incubators' performance has been subject to debate. Different methods and evaluation parameters have been used to evaluate incubator models. During the 1990s,

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in-depth studies were carried out into incubator performance, and also to be used for benchmarking (Bhabra-Remedios and Cornelius 2003, p. 12), but without establishing a single evaluation framework (Mian 1997). In this way, some evaluations were done comparing performance indicators (Chan and Lau 2005, p. 1217; Grimaldi and Grandi 2005).

Each university has its own rules and context, and a standard method is not easily transferable from one university to another (Moray and Clarysse 2005). For example, such an important issue like the intellectual property policy adopted by the university can clearly mark the spin-off typology. In our case study, the intellectual property from research projects belongs to CEIT, not its researchers, and in the majority of the cases this aspect regulates how spin-offs are born. Specifically this study is focused on an UBI that has not been established for the support of mature firms, but for early stage ventures. Studying the assessment of its performance in high-tech spin-offs, we try to provide implications to incubator managers.

2 Incubator and the Case Study (CEIT)

Searching a definition of "incubator" a large number of approaches and similar definitions have been introduced (Hackett and Dilts 2004). The variety of incubating organizations is because of the evolution of companies' requirements and needs, but also because of the incubator sponsor's interests (Mian 1996). This paper doesn't try to generalize, but to provide to similar University Business Incubators (UBIs) with useful indications on how to strategically position themselves.

UBIs can be placed somewhere between the two incubators models proposed by Grimaldi and Grandi (2005, p. 114). On one hand UBIs are oriented towards the provision of tangibles assets (mainly logistical services) and market commodities at low prices, but on the other hand UBIs provide support to new knowledge-based spin-offs, emphasising on the transfer of scientific and technological knowledge and providing effective mechanisms for weaknesses of traditional public incubating organisations ("…university-technology start-ups relationship is found more useful than the science park-technology start-up relationship with regards to the product development…" Chan and Lau 2005, p. 1227).

The case study of this paper is based on eight spin-offs of CEIT whose incubator model fits very well with one proposed by Bergek and Norrman (2008 p. 22) "…concept of incubator is reserved for organisations that supply joint location, services, business support and networks to early stage ventures". Most researchers seem to agree that incubation is related to the early phase of a venture's life, where ideas are still immature and have not yet been fully become in business (Klofsten 2005), and the incubator help them to develop as sustainable firms (Bhabra-Remedios and Cornelius 2003; Hackett and Dilts 2004; Grimaldi and Grandi 2005). And at the same time, CEIT incubator model is "inward-oriented" according to Grimaldi and Grandi (2005, p.115): "inward-oriented: give priority to business ideas coming from their parent organizations". Following the literature review done by Bergek and Norrman (2008), the main incubator model components are: Selection, Infrastructure, Business support, and Mediation. Following Bergek proposal, the Selection parameter of CEIT incubator model fits well with the "Picking-the-winners" approach, under which incubator managers try to identify a few potentially successful and viable ventures, but having a relationship at the same time with the research lines of the university, who is the incubator sponsor. In relation to Infrastructure component, most incubators seem to supply similar administrative services and CEIT incubator doesn't offer anything different. With respect to Business support it depends on the profile and expertise of the entrepreneur and what he demands in each moment. Nowadays CEIT incubator managers have gained experience over the years and they are available to offer mediation, mentoring and coaching to entrepreneurs, that in the majority of the cases it is their first time creating a new firm. Therefore this paper focuses on an UBI that has not been established for giving support to mature firms, otherwise to early stage ventures.

3 The Assessment Framework and Data Collection

Based on the literature and the questionnaire and interviews with eight CEOs of CEIT's spin-offs and also with CEIT incubator's staff we point out mainly eight services offered by the incubator, which are proposed by this study as the assessment framework:

1. Recruitment process for external CEO: The typology of spin-offs promoted by CEIT incubator are clearly marked by two main aspects: (i) the IP policy of its sponsor, where the intellectual property mostly belongs to the centre, and (ii) the low entrepreneurial spirit of researchers. These two handicaps bring to CEIT incubator to create what we call "fatherless spin-offs": new ventures based on a technology that has been developed internally in the centre but without the figure of an entrepreneur. Consequently, incubator has to recruit an external entrepreneur to act as CEO and to lead and take charge of the new venture.
2. Facilities and administrative provision: Any service focused to reduce spin-offs costs is always welcomed by CEOs, even more in early stages. To offer office spaces, tangible assets (mainly logistical services) covering all the typical indirect costs (light, internet, phone…) are a valuable service for tenant firms. Moreover, the possibility of using modern laboratories and facilities of a university is a fundamental condition for technological ventures.
3. Latest technology and knowledge support: This is one of the most important advantages of UBIs in comparison with other typologies of incubator. It is assumed that spin-offs born from university are mostly based on latest technologies, and UBIs combine all the requirements to offer a good technical support.

4. Incubator image and credibility: To be tenant of an UBI usually carries a certain degree of credibility and image, or at least more than those born without any sponsor. A good technical and professional image is usually associated to academic spin-offs, however this is not the case with regards to market orientation and its credibility as feasible business.
5. Funding for the first early stage: The main handicap for recent firms is to get capital in the earliest stage, because it is the biggest risk moment and consequently there are not entities willing to invest. This is the typical need that should be taken into account by public policies if they really want to promote new technological ventures in the region.
6. Networking: Raise external financial partners. The spin-offs of this case study are mostly focused to traditional sectors which normally are featured by high entry barriers in terms of capital equipment, and financial partners search becomes essential. Depending on the credibility of the UBI regional financial partners can be more disposed to invest in its tenant firms.
7. Networking: customers. In the case of CEIT, where the half of the income comes from bilateral research projects with industry, the incubator could offer some interesting contacts that can become clients of the tenant firms, and in some cases even industrial partners for the venture.
8. Coaching: To find and select the appropriated partner profile, to negotiate and agree the shareholders agreement or to lead the Shareholders Board are some examples that have to be performed by the entrepreneur, that in most of the cases are their first time. Entrepreneurs demand these coaching services for the incubator. They need to be helped in filling the managerial and business competencies gap, that in some cases it is one of the typical weaknesses of academic spin-offs.

An important services' characteristic obtained from the interviews is that there is a turning point when the spin-off is ready to find an external financial partner. The spin-off gets another dimension and consequently needs and services demanded are different. We have detected two phases: Phase I, before that turning point, and Phase II, afterwards. The interviews identifies that the parameters Incubator image and Funding for early stages are services that play the role of a bridge between both phases.

4 Application of the Assessment Framework

Like other research (Mian 1997; Chan and Lau 2005), this paper checks the above assessment framework using a case study approach, that in this case is applied in eight high-tech spin-offs that born in CEIT incubator (Table 1). Being CEIT a multidisciplinary research centre, the eight incubated spin-offs that have been studied are also focused on different fields: water engineering, training simulators, on-line color machine vision, communication solutions, high performance metallic

Table 1 The eight spin-offs used in this case study

	1	2	3[a]	4	5	6	7	8[b]
Years of life[c]	>10	>10	5–10	5–10	5–10	5–10	5–10	5–10
Field	Water	ICT	ICT	ICT	Metallurgy	Water	ICT	Bio
Employees	25–50	25–50	0	<25	<25	<25	<25	0

[a]Spin-off no. 3 had an innovative machine based on specific artificial vision. It was oriented to real estate sector, and due to the crash of the housing bubble, the company had to close

[b]Spin-off no. 8 was created to exploit several tech-products in the health sector that required an important quantity of capital. The economic crisis caused the abandonment of the investors and consequently the closure of the venture

[c]Years of life means the age of the firm. Spin-offs stay in CEIT's incubator no more than one year

Table 2 Classification of the eight spin-offs studied according to the origin

Origin	External CEO	Internal CEO (researcher)	Specific knowledge	Generic knowledge
Researcher promoter	0	4	1	3
Incubator promoter	4	0	4	0

powders, membranes for wastewater treatment, ultra-low power RFID passive sensors, and biotechnology. Four of these eight ventures were acquired by multinational companies.

Through the interviews and the questionnaire carried out in this study, a distinctive and differential feature was clearly identified: the way how the spin-off was created. We found clearly two differentiated origins: when the promoter is an internal researcher of the centre, or when the promoter is the incubator itself. In the first case, the researcher becomes directly to CEO, while in the second case the incubator needs to play the role of "headhunter" and tries to find a CEO out of the university (external CEO). This last case is what we call "fatherless spin-off", because the new venture idea exists but there is not an entrepreneur. As Table 2 shows, four of our eight spin-offs were fatherless ventures (external CEOs), and the other four were promoted directly by internal researchers. Curiously, the CEOs of the eight spin-offs are alumni of the university that is the sponsor of the incubator, what indicates how important is to foster the entrepreneurial spirit at the education stage as a way to increase the creation of new ventures.

The spin-off typology that emerges with this study has some relationship with the model proposed by Bathelt et al. (2010), which classifies spin-offs from a knowledge perspective: generic or specific. In our case study, when the promoter of the new venture is a researcher, the venture is based on a specific knowledge that has been developed internally in the university in just one of the four cases, meanwhile in fatherless spin-off, when the spin-off is promoted by the incubator, it is based on a specific and internal knowledge in all the cases.

5 Assessment of Incubation Model

The eight studied spin-offs assessed the services of the incubator scoring among four values (0: Nothing, 1: Low, 2: Medium, 3: High), and Table 3 shows the obtained mean score. Obviously the first service, Recruitment Process, is not scored by the spin-offs because it is a special service that can be assessed only by the incubator sponsor. In relation to this service we can say that two of the four external CEOs still continue in the spin-off, and the other two left the venture, and new recruitment process had to be done to find two substitutes. In both cases the ventures performed significantly better, what confirms the finding of Lundqvist (2014) in relation to the surrogate entrepreneurs as one way to improve entrepreneurial team formation and venture results.

In relation to Facilities provision service, the obtained score was very similar in both cases, researcher and incubator origin. The obtained score of this service was high: CEOs saw it as relevant to be close to the facilities of the centre because of the technology support. In spin-offs with generic knowledge this need is not so urgent. On the contrary, Technology support service was much more valued by spin-offs with external CEOs because their professional profile is not so technical. Therefore, as a result of this technical formation gap, the dedication of incubator resources spills over to spin-offs with external CEOs and specific knowledge. The score obtained in the Incubator image parameter was higher by spin-offs with an incubator sponsor origin, and less by firms with generic technology. Other issue is that the high tech spin-offs studied in this article require many resources to try to bring the technology to market and this is the main reason why Funding service for early stage was so low valued in both cases, even more in firms with specific knowledge.

The scores for services of Phase II are significantly lower. Once the spin-off is near to market, incubator is not able to meet the day to day demands of the spin-off, starting. Regarding to Network of customers, this service was the lowest assessment by the two types of spin-offs. The staff of the incubator recognized the gap they had in this field and the low help they offered. In Phase II the needs of the firms have an

Table 3 Assessment of CEIT incubation

	Spin-off's origin	
Assessment criteria	Researcher	Incubator sponsor
Recruitment process for external CEO	–	–
Facilities and administrative provision	2.25	2.75
Latest technology and knowledge support	1.50	3.00
Incubator image and credibility	2.25	3.00
Funding for the first early stage	1.00	1.50
Networking: raise external financial partners	1.25	1.75
Networking: customers	1.25	0.25
Coaching	1.25	1.25

0 Nothing, *1* Low, *2* Medium, *3* High increasing focus on more intangible and high-value services. The Coach service was very low valued by both types of origin (the incubator fails in this service, like in the rest of services of Phase II). We thought that CEOs with more technical profile and less business formation would be more open and receptive to assistance and advice, but both profiles required this service.

6 Conclusions

The incubator model, the idiosyncrasy of the incubator sponsor (university), the typology of the tenant firm according its origin and the type of the core knowledge of the spin-off (specific or generic) are key parameters to strategically position the incubator. This paper considers the models used in the literature and proposes an alternative assessment framework as a tool to incubator managers to provide them useful indications:

1. When the incubator selects not only a new business idea for entry, but also the external entrepreneur to manage it as CEO, the needs, the services and the resources dedication of the incubator change significantly. "Fatherless spin-offs" demand more support in services of Phase I compared to spin-offs with internal researchers as CEOs.
2. A good recruitment process for external entrepreneurs is a service that is required by the sponsor of this model of incubator. To find the correct CEO profile for this kind of young high-tech ventures is not easy at all, and one of the advantages of UBIs is the direct relation with the university alumni, which is a large source to find good professionals. The total eight CEOs of this case study belonged to the university alumni, and we think that this is another disadvantage that other types of incubators have got.
3. In fatherless spin-offs, the CEO comprehension of the technology and sector takes an intense amount of time, and they are grateful for the knowledge and technological support by UBI. On the contrary, the case of researchers as CEOs the needs are totally different. They demand more network, coach and business and market oriented services and less technology support. In Phase I the positioning of the incubator should be more oriented to fatherless spin-offs. Meanwhile in Phase II, where the firm is closer to market, both typologies of spin-off require help, and the incubator should strategically position and improve its services.

The collecting data that has been used comes from only one incubator and it would be advisable to test this study with other incubators to understand better the importance of the spin-off's origin and how this can affect to the UBI model.

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Part II
Operations Research, Modelling and Simulation

A Novel Project Selection Scheduling Model

H. Amirian and Rashed Sahraeian

Abstract In this paper, the optimal selection of portfolio of projects is addressed. The problem is examined at operational level where every project has several jobs with certain costs, profits and due dates. The duration of each job is affected by learning effect and its setup time is dependent on the sequence and processing times of the jobs prior to it. Any profit gained from the completion of a job is reinvested in the portfolio and the time horizon is assumed flexible. The objective is to maximize the total revenue of the selected projects. A mixed integer model is presented and analyzed to address this problem.

Keywords Project selection scheduling · Reinvestment strategy · Learning effect · Setup time · Flexible time horizon

1 Introduction

Project selection scheduling problem (*PSSP*) is one of the most practical problems in project management, portfolio management, risk and investment management, and has drawn great attention in recent years (Jafarzadeh et al. 2015). The problem under study is a modification of *PSSP* and can be defined as follows. Several projects with same priorities are available for investment. Each project has several jobs. Projects can be interrupted, but if a job starts, it should be processed until its completion. The objective is to select a portfolio of projects and schedule their jobs within an optimal time horizon in order to maximize the total profit subject to the following conditions. Available budget and resources are limited and shared among the projects. Moreover, similar to Chen and Askin (2009), it is assumed that the

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amount of profit achieved from the completion of each job is added to the current budget to be used for the next investment. The planning horizon is defined in prior, but time slacks are assigned to this horizon so that, considering the objective, the best time horizon can be decided with addition of slacks. Any deviation from the default time horizon results in loss or gain depending on the fact that the planning is finished later or earlier than expected, respectively. Implementation of each job needs a certain amount of investment and resources which should be available at the start of that job. Each job has a due date, a percentage of learning effect and a past-sequence-dependent (*psd*) setup time. If due dates are not met, a separate cost is inflicted on the project at the end of its completion. If a job is part manual, part machine-based, then only the manual part undergoes learning. Learning effect refers to the fact that as the time goes on, the duration of a job decreases due to the increase in the operator's skill to perform that job (Peteghem and Vanhoucke 2015). As the name indicates, *psd* setup time of a job has a variable value which is dependent on the sequence and processing times of its previous jobs. This type of setup time is mostly seen in industries such as chemical, textile, metallurgical, printed circuit board, and automobile manufacture (Amirian and Sahraeian 2015). In this paper, a mixed integer model is proposed based on the model first presented in Belenky (2012) and later corrected by Jafarzadeh et al. (2015). Their problem was limited to selection and scheduling of projects alone, while we also consider jobs of each project, their due dates, resource usages, setup times and their learning effects. Moreover penalties for tardiness of jobs are added to the objective. The idea is that breaking a project to its jobs and studying the problem at an operational level rather than a strategic level gives a more realistic view to selecting and scheduling of projects.

2 Problem Formulation

There are m projects available ($i = 1, \ldots, m$) with setup dependency parameters of b_i and each project has V_i jobs ($v = 1, \ldots, V_i$). Each job with duration of w'_{iv}, rate of machine time M_{iv} $(0 \leq M_{iv} \leq 1)$ and learning parameter of a_{iv} $(0 \leq a_{iv} \leq 1)$ needs r_{iv} resources to commence. A job needs to meet its due date D_{iv}, otherwise a penalty of β_{iv} is occurred. The achieved profit and cost requirement in time h for job v of project i which has started at time j are denoted as $d_{ivj}(h)$ and $c_{ivj}(h)$ respectively. Maximum available resource at time j is R_j and P is the *initial* available budget. The gain (loss) in each additional period j, due to finishing all projects sooner (later) than the default time horizon is denoted by $\alpha_j > 0$ $(\alpha_j < 0)$. The default time horizon is T periods ($h, h', j = 1, \ldots, T$), the slack values $\lambda_{\max}, \lambda_{\min}$ show the upper and lower bounds of time horizon tolerance and we have $\hat{\lambda} = \max\{|\lambda_{\max}|, |\lambda_{\min}|\}$. The decision variable x_{ivj} equals 1 if job v of project i starts at time j and 0 otherwise. Binary variable y_j counts the number of planning periods skewed from time T. The completion time of each job is Co_{iv} and the numbers of executive time periods that planning is finished later or earlier than time T are λ^{+} and λ^{-}, respectively. The state variables are the lateness L_{iv} and tardiness $TA_{iv} = \max(0, L_{iv})$ of each job. Additional state variables are *psd* setup time s_{ivj} and learning processing time $w_{ivj}(h')$ at time h' for job v of project i which has started at time j. Processing time under the effect of learning is formulated with the assumption that if a job is continued uninterrupted, then the operator becomes more experienced as the time goes on. Thus, if h' and j are the current time and the starting time of a job, respectively, then the longer a job is processed (i.e. the greater $h' - j$ is), the more affected its processing time by learning. Also it is assumed that learning has a meaningful effect if processing time of a job is higher than one. Equations (1) and (2) formulate the partial and complete learning processing times of each job. Similarly, setup times can be formulated according to Eqs. (3) and (4). Since there is no job before the first job of each project, $s_{i[1]j}$ for all projects and periods equal to zero.

$$w_{ivj}(h') = 1/(M_{iv} + (1 - M_{iv}).(h' - j)^{a_{iv}}) \tag{1}$$

$$w_{iv} = \sum_{j=1}^{T+\lambda_{\max}-\sum_{f=v}^{V_i} w'_{if}} x_{ivj} \sum_{h'=j+1}^{w'_{iv}+j} w_{ivj}(h') \quad \forall i = 1,\ldots,m;\ \ v = 1,\ldots,V_i \tag{2}$$

$$s_{ivj} = b_i \sum_{f=1}^{v-1} w_{if} \sum_{t=1}^{j-1} x_{ift} \quad \forall i = 1,\ldots,m;\ \ v = 2,\ldots,V_i;\ \ j = 1,\ldots,T+\lambda_{\max} \tag{3}$$

$$s_{iv} = \sum_{j=1}^{T+\lambda_{\max}-\sum_{f=v}^{V_i} w_{if}} x_{ivj}.s_{ivj} \quad \forall i = 1,\ldots,m; v = 2,\ldots,V_i \tag{4}$$

The objective function in Eq. (5) seeks to maximize the achieved profit at the end of the optimal planning horizon. It consists of five parts: the initial profit, the profit achieved by the jobs finishing at the last period, the profit extracted from the jobs finishing during the planning horizon, the loss occurred by finishing a job later than its due date and finally the penalty (gain) due to completing all selected projects after (before) the original planning horizon. Constraints (6) and (7) focus on the limitation on expenditure in each period while considering reinvestment strategy. Equation (8) emphasizes that each job of a project starts only once during the time horizon. Constraint (9) ensures that the resource usage of all jobs in a period cannot exceed the available resources in that particular period. Equations (10)–(13) formulate the scheduling part of the problem where the completion times of all jobs and their lateness values are achieved. Equations (14) states that each project should finish within the flexible time horizon i.e. the default time horizon plus the positive and negative time slacks. Equations (15) and (16) count the number of periods that planning is finished sooner or later than the original time horizon, respectively. Equation (17) ensures that the start of each additional period should not exceed the maximum optimal time horizon. Equation (18) states that if a project is not finished early at time $j+1$, it means it wasn't finished at time j neither. Basically, this equation makes sure the numbers of periods that projects are finished earlier than planned are calculated correctly. Equations (19) and (20) are either/or equations and make sure that either λ^{+} or λ^{-} gets a value higher than zero. Equation (21) limits the optimal slacks between the minimum and maximum slacks. Equation (22) explains the decision variables.

$$\begin{aligned} \max Z = P + \sum_{i=1}^{m}\sum_{v=1}^{V_i}\sum_{j=1}^{T+\lambda_{\max}-\sum_{f=v}^{V_i}(w_{if}+s_{if})-1} d_{ivj}(T+\lambda_{\max}).x_{ivj} \\ + \sum_{i=1}^{m}\sum_{v=1}^{V_i}\sum_{j=1}^{T+\lambda_{\max}-1}\sum_{h=1}^{T+\lambda_{\max}-1}(d_{ivj}(h)-c_{ivj}(h)).x_{ivj} \\ - \sum_{i=1}^{m}\sum_{v=1}^{V_i}\beta_{iv}.TA_{iv} + \sum_{j=T+\lambda_{\min}}^{T+\lambda_{\max}}\alpha_j.y_j \end{aligned} \tag{5}$$

s.t.

$$\sum_{i=1}^{m}\sum_{v=1}^{V_i} c_{iv[1]}(1).x_{iv[1]} \le P \tag{6}$$

$$\begin{aligned} \sum_{i=1}^{m}\sum_{v=1}^{V_i}\sum_{j=1}^{k} c_{ivj}(k).x_{ivj} \le P + \sum_{i=1}^{m}\sum_{v=1}^{V_i}\sum_{j=1}^{k-1}\sum_{h=1}^{k-1}(d_{ivj}(h)-c_{ivj}(h)).x_{ivj} \\ + \sum_{i=1}^{m}\sum_{v=1}^{V_i}\sum_{j=1}^{k-1} d_{ivj}(k).x_{ivj} \quad \forall k = 2,\ldots,T+\lambda_{\max} \end{aligned} \tag{7}$$

$$\sum_{j=1}^{T+\lambda_{\max}} x_{ivj} \le 1 \quad \forall i = 1,\ldots,m;\ \ v = 1,\ldots,V_i \tag{8}$$

$$\sum_{i=1}^{m}\sum_{v=1}^{V_i} r_{iv}.x_{ivj} \le R_j \quad \forall j = 1,\ldots,T+\lambda_{\max} \tag{9}$$

$$\begin{aligned} Co_{i[v+1]} \ge Co_{iv} + \sum_{j=1}^{T+\lambda_{\max}-\sum_{f=v+1}^{V_i} w'_{if}} \sum_{h=j+1}^{j+w'_{i[v+1]}} x_{i[v+1]j}.(w_{i[v+1]j}(h)+s_{i[v+1]j}) \\ \forall i = 1,\ldots,m;\ \ v = 1,\ldots,V_i - 1 \end{aligned} \tag{10}$$

$$Co_{i[1]} \geq 1 + \sum_{j=1}^{T+\lambda_{\max}-\sum_{f=1}^{V_i} w'_{if}} \sum_{h=j+1}^{j+w'_{i[1]}} x_{i[1]j}.w_{i[1]j}(h) \quad \forall i = 1, \ldots, m \tag{11}$$

$$Co_{iv} - D_{iv}. \sum_{j=1}^{T+\lambda_{\max}} x_{ivj} = L_{iv} \quad \forall i = 1, \ldots, m; v = 1, \ldots, V_i \tag{12}$$

$$Co_{iv} \leq H. \sum_{j=1}^{T+\lambda_{\max}} x_{ivj} \quad \forall i = 1, \ldots, m; \;\; v = 1, \ldots, V_i \tag{13}$$

$$\sum_{j=1}^{T+\lambda_{\max}-\sum_{f=1}^{V_i} w'_{if}} j.x_{i[1]j} + \sum_{v=1}^{V_i} \sum_{j=1}^{T+\lambda_{\max}-\sum_{f=v}^{V_i} w'_{if}} x_{ivj}.(w_{iv} + s_{iv}) \leq T + \lambda^+ - \lambda^- \quad \forall i = 1, \ldots, m \tag{14}$$

$$\sum_{j=T+\lambda_{\min}}^{T-1} y_j = \lambda^- \tag{15}$$

and

$$\sum_{j=T+1}^{T+\lambda_{\max}} y_j = \lambda^+ \tag{16}$$

$$jy_j \leq T + \lambda^+ \quad j = T+1, \ldots, T+\lambda_{\max} \tag{17}$$

and

$$y_j \leq y_{j+1} \quad j = T+\lambda_{\min}, \ldots, T-2 \tag{18}$$

$$\lambda^+ \leq (1-\delta)\hat{\lambda} \tag{19}$$

and

$$\lambda^- \leq \delta\hat{\lambda} \tag{20}$$

and

$$\lambda_{\min} \leq \lambda^+ - \lambda^- \leq \lambda_{\max} \tag{21}$$

$$free(L_{iv}), Co_{iv} \geq 0 \quad \forall i = 1,\ldots,m;\;\; v = 1,\ldots,V_i;\;\; int(\lambda^+, \lambda^- \geq 0),\;\; \delta \in \{0,1\}$$
$$y_j \in \{0,1\} \quad \forall j = T + \lambda_{\min},\ldots,T + \lambda_{\max},$$
$$x_{ivj} \in \{0,1\} \quad \forall i = 1,\ldots,m;\;\; v = 1,\ldots,V_i;\;\; j = 1,\ldots,T + \lambda_{\max} \tag{22}$$

3 Model's Analysis

In order to illustrate the performance of the proposed model, a numerical example is examined in details as follows. Suppose four projects are available to pursue and projects one to four have 3, 2, 5 and 4 jobs respectively. The management should decide which project to follow and how to schedule its jobs. The costs $c_{ivj}(h)$ and profits $d_{ivj}(h)$ of different jobs of the projects are summarized in Table 1. Note that any costs or profits that are not included in the table get the value of zero. The normal processing times, required resources and due date penalties for the jobs are summarized in Table 2. The default planning horizon has 6 periods (i.e. $T = 6$) and the assigned time slacks are considered $\lambda_{\min} = -1, \lambda_{\max} = 18$. Hence, the planning horizon would be flexible in range $[T-1, T+18]$ i.e. $[5, 24]$. The due dates are calculated as $D_{iv} = 6 - \sum_{f=v+1}^{V_i} w'_{if}$. The initial budget is set as 2000 ($P = 2000$). The maximum renewable resources for each period are considered 30 ($R = 30$).

Table 1 Costs and profits of different jobs of projects

Project	Costs	Profits
1	$c_{111}(1) = 350, c_{122}(2) = 800$ $c_{134}(4) = c_{134}(5) = 220$	$d_{134}(6) = 1200, d_{111}(2) = d_{122}(3) = 400$
2	$c_{211}(1) = 350, c_{222}(2) = 250$	$d_{211}(2) = d_{222}(3) = 750$
3	$c_{314}(4) = 350, c_{314}(6) = 450$ $c_{34[14]}(14) = c_{35[17]}(17) = 250$ $c_{314}(5) = c_{328}(8) = c_{33[10]}(10) = 250$	$d_{314}(7) = 1200, d_{328}(9) = d_{33[10]}(11) = 400$ $d_{34[14]}(15) = d_{35[17]}(18) = 400$
4	$c_{411}(1) = 350, c_{423}(3) = 2005$ $c_{411}(2) = c_{448}(8) = 250, c_{436}(6) = 150$	$d_{423}(4) = 2750$ $d_{411}(2) = d_{436}(7) = d_{448}(9) = 275$

Table 2 Normal durations, required resources and due date penalties of jobs

Project	Normal durations	Required resources	Due date penalties
1	$w'_{[1]v} = \{1,1,2\}$	$r_{[1]v} = \{10,10,4\}$	$\beta_{[1]v} = \{10,10,10\}$
2	$w'_{[2]v} = \{1,1\}$	$r_{[2]v} = \{10,10\}$	$\beta_{[2]v} = \{5,5\}$
3	$w'_{[3]v} = \{3,1,1,1,1\}$	$r_{[3]v} = \{10,10,4,5,10\}$	$\beta_{3v} = \{3,3,3,3,3\}$
4	$w'_{[4]v} = \{2,1,1,1\}$	$r_{[4]v} = \{10,20,4,5\}$	$\beta_{4v} = \{2,2,2,2\}$

Table 3 A feasible solution

Project	x	Co	L
1	$x_{111} = x_{122} = x_{134} = 1$	$Co_{11} = 2, Co_{12} = 3.5, Co_{13} = 6.25$	$L_{11} = -1, L_{12} = -0.5, L_{13} = 0.25$
2	$x_{211} = x_{222} = 1$	$Co_{21} = 2, Co_{22} = 3.5$	$L_{21} = -3, L_{22} = -2.5$
3	$x_{314} = x_{328} = x_{33[10]} = 1$ $x_{34[14]} = x_{35[17]} = 1$	$Co_{31} = 7.02, Co_{32} = 9.22, Co_{33} = 11.92$ $Co_{34} = 15.11, Co_{35} = 18.81$	$L_{31} = 5.02, L_{32} = 6.22$ $L_{33} = 7.9, L_{34} = 10.11, L_{35} = 12.8$
4	$x_{411} = x_{423} = 1$ $x_{436} = x_{448} = 1$	$Co_{41} = 2.7, Co_{42} = 4.6$ $Co_{43} = 7.01, Co_{44} = 9.89$	$L_{41} = -0.24, L_{42} = 0.63$ $L_{43} = 2.01, L_{44} = 3.89$
Other variables	$\lambda^+ = 12, \lambda^- = 0, y_{j=7,\ldots,18} = 1, \delta = 0$		

Table 4 Learning durations and *psd* setup times of different jobs

Project	Learning durations	Setup times
1	$w_{[1]v} = \{1, 1, 1.75\}$	$s_{[1]v} = \{0, 0.5, 1\}$
2	$w_{[2]v} = \{1, 1\}$	$s_{[2]v} = \{0, 0.5\}$
3	$w_{[3]v} = \{2.39, 1, 1, 1, 1\}$	$s_{[3]v} = \{0, 1.19, 1.69, 2.19, 2.69\}$

Table 5 Resource usage in different points in time

Time	Resource	Time	Resource	Time	Resource
1–2	30	4.63–6.01	14	9.22–9.89	5
2–2.5	10	6.01–6.25	18	9.89–10.92	0
2.5–2.75	30	6.25–7.01	14	10.92–11.92	4
2.75–3.5	20	7.01–7.02	10	11.92–14.11	0
3.5–3.63	0	7.02–8.22	0	14.11–15.11	5
3.63–4.5	20	8.22–8.89	10	15.11–17.81	0
4.5–4.63	24	8.89–9.22	15	17.81–18.81	10

The lateness penalties for periods 7–24 are set as $\alpha_7 = -10, \alpha_8 = -11$, $\alpha_9 = \alpha_{10} = \alpha_{11} = -12$ and $\alpha_{j=12,\ldots,24} = -13$. Also let $M = 0.25, a = 0.515, b = 0.5$. One possible solution for this problem is shown in Table 3. Replacing the values for x_{ivj} from Table 3 in Eqs. (1)–(4) yield the processing and setup times under learning, shown in Table 4. As an example, according to Eqs. (1) and (2), $w'_{41} = 2$ reduces to 1.7565 as: $w_{41} = x_{411}(w_{411}(2) + w_{411}(3)) = 1 \times (1 + 0.7565)$. Similarly for setup times, according to Eqs. (3) and (4), we have $s_{43} = x_{434} \times s_{434}$ where $s_{434} = b_4 \times (w_{41} \times x_{411} + w_{42} \times x_{423})$ which is: $0.5 \times (1.7565 \times 1 + 1 \times 1) = 1.3782$. Also the resource usage variations during the planning horizon are investigated in Table 5. Note that the used resources are all less than or equal to the maximum available resources (i.e. 30). The final scheduling of such a problem is illustrated in Fig. 1. Now, consider project 4, where its second job needs $c_{42j}(h) = 2005$ to start. If the classic version of investing was considered where our only source of asset was the initial capital of $P = 2000$, then project 4 would not have been selected since one of its jobs needs more than the available budget of 2000. If we had forgone the selection of project 4, the total profit from selecting projects 1 and 2 would have been 3307.5 according to Eq. (5). However, with reinvestment strategy, the profits of other projects accumulate to 2225 at the start of this job in time 3.6348. This makes it possible to select project 4 and the final profit increases to 3831.4214. On the other hand, if time horizon was fixed at $T = 6$, then project 3 would not have been chosen since its duration surpasses 6 periods. However with flexible time horizon strategy, planning horizon is increased from 6 to 24 which makes it possible to select project 3, and in turn, the profit has increased from 3831.4214 to 4160.1814.

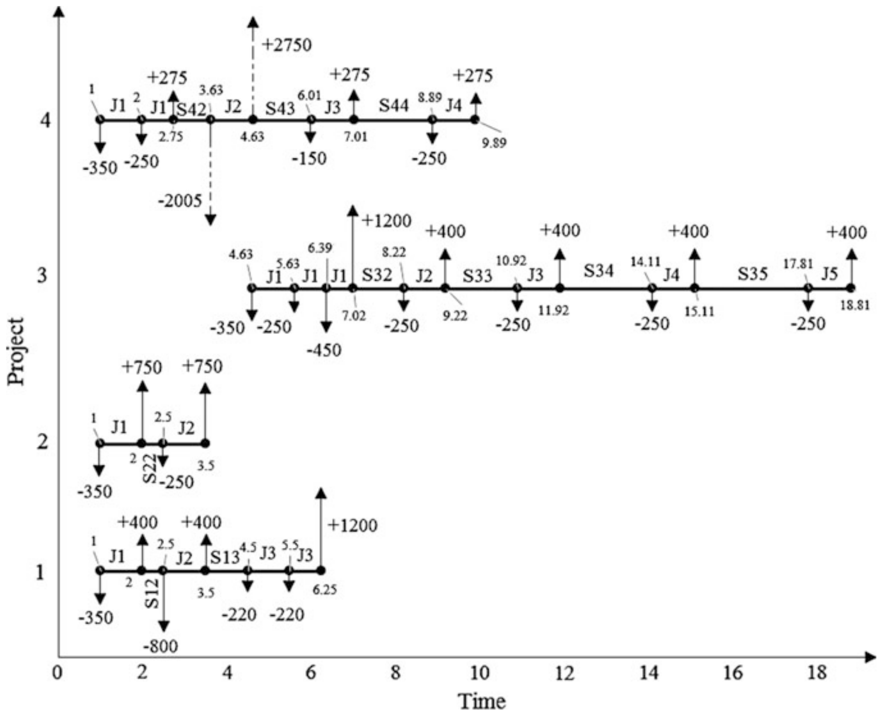

Fig. 1 Feasible schedule with *psd* setup time and learning effect

In summary, adding setup times and learning effect result in a more realistic planning while the reinvestment strategy and flexible horizons provide an opportunity for increasing the final profit by enabling to include more projects in the portfolio.

4 Conclusion

In the current paper, a model on the integrated problem of project selection and scheduling is presented. First, past sequence dependent setup times and learning effects are added to the jobs of each project to provide a more realistic view on scheduling. Second, reinvestment strategy is considered which makes it possible to include a project in the portfolio even if its cost is higher than the initial capital at hand. Third, time horizon is assumed to be flexible. This assumption weighs the benefit versus loss of adding another additional period to the default planning horizon. The effects of these strategies are investigated using a numerical example. Future works on the subject involve considering uncertain parameters in the model and developing appropriate simulation methods to tackle the problem.

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Resolving Product Configuration Conflicts

Vladimir Modrak, Slavomir Bednar and Zuzana Soltysova

Abstract The main objective of this paper is to propose an approach to resolve product configuration conflicts based on the previously developed framework for product component modelling in terms of mass customization and original matrix method, by which it is possible to determine the number and structural designs of all relevant product configurations.

Keywords Product configuration · Constraint satisfaction problem · Incidence matrix

1 Introduction

Product configuration conflicts are matter of interest especially in terms of mass customization (MC). This marketing strategy allows customers to make decisions either on buying standard product of lesser preference fit, or buying a MC product providing a better preference fit at a higher price, they are actually willing to pay (Du and Tseng 1999; Gecevska et al. 2010; Matt 2010). Such customizable product reflects so called configuration variety and requires a key enabling and sophisticated tool support to automate the process of final product configuration. Configurators can provide this variety extent to customer in understandable and simple manner taking component restrictions and compatibility into account. Moreover, it was found that it is reasonable to identify and eliminate so called excess variety already in the product design stage (see, e.g. Dima et al. 2010; Krus 2015).

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This paper presents an original generic solution of CSPs by which managers can easily and precisely identify the extent of offered variety. For this case, a model of personal computer and its components has been used do demonstrate the proposed approach. The agenda of this paper is as follows: Sect. 2 brings a short overview of related approaches and solutions to CSP in the most cited disciplines. The following Sect. 3 presents our previously developed approach to product component modelling for imaginary variety without restrictions—so called product configuration complexity approach. Subsequently, Sect. 4 introduces our new proposed approach to CSP capable of enumerating variety for any restricted component (product) assembly model. Finally, Sect. 5 summarizes pros and cons of the approach and proposes further research objectives in this direction.

2 Related Work

A number of research findings have been reported on configuration problem-solving in terms of mass customization (see e.g., Felfernig et al. 2002; Ong et al. 2006). The main effort is usually aimed to identify possible product configuration solutions with respect to configuration rules and/or restrictions. Recently, CSPs are becoming the main problem-solving methodology to product configuration and variety solutions, respectively (Fleischanderl et al. 1998; Stumptner et al. 1998; Frutos et al. 2004; Xie et al. 2005; Ong et al. 2006; Aldanondo and Vareilles 2008; Yang et al. 2009; Liu et al. 2010; Wang et al. 2011a, b). According to Giovannini et al. (2013), manufacturability of all possible MC product alternatives should be verified already in the product and manufacturing process design stage. Various CSP-based approaches are aimed to identify single, multiple or all possible product alternatives. Lin et al. (1996) defined a concept for customer requirements management process and introduced a formal way of representing the knowledge as part of their developed tool. They considered customer needs to be fuzzy and incomplete. Other authors (Inakoshi et al. 2001; Li et al. 2006) have developed a tool running on case-based reasoning and constraint satisfaction solutions by using a personal computer configurator to describe the extent of customer needs. Wang et al. (2011a, b) proposed a relevant method to the one in this paper. They established a process to transform customer requirements into product functions and then to product modules.

3 Framework for Product Component Modelling

In order to identify all possible restricted product alternatives, firstly let us provide our previously developed approach to determine all possible product alternatives without component restrictions (Modrak et al. 2012, 2014, 2015; Modrak and Bednar 2015). Component is seen as a part of the product. Accordingly, we can

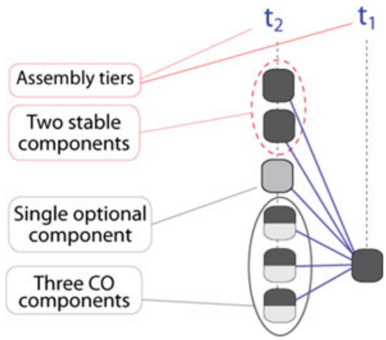

Fig. 1 Basic model of MC assembly consisting of three component types

divide components into three groups: stable components i, voluntary components j, and compulsory optional components k. Model of component structure in Fig. 1 contains two stable components, one voluntary and three compulsory optional components. When we talk about stable components (i), they are fixed in the final component structure. Voluntary components (j) are those, which are optional in selection. There is a possibility to choose a desired number from all available optional components or all of the components. Compulsory optional components (k) are optional, but with minimum and maximum requirements "l" on a selection by customer, where $1 \leq l < k$. They have three selecting options regarding l components to be selected from all k:

- Individual selectivity rule where we select individual value l of k components (e.g. select exactly 2 out of 5 components as: $\binom{k}{l} = \binom{5}{2}$);
- Maximum selectivity rule where we select maximum l out of k components
- Minimum selectivity rule where we select at least l of k components (e.g. select min. 2 out of 5 components: $min\binom{k}{l} = min\binom{5}{2}$).

Further, it is shown by an example, how to quantify all possible product configurations on the product structure from Fig. 3. This case will not consider compulsory optional components. Let us have a situation with combination of two stable components that are CD-unit and Pentium I, moreover one voluntary component that is OS-Operating system. Formally written as $i = 2$, $j = 1$, $k = 0$. Then the number of all possible configurations can be calculated as follows:

$$\sum Conf = \sum_{j=0}^{n} \left(\frac{j!}{n!(j-n)!}\right) \rightarrow \left[\left(\frac{1!}{0!(1-0)!}\right) + \left(\frac{1!}{1!(1-0)!}\right)\right] = (1+1) = 2. \quad (1)$$

Another situation, so called scenario is with inclusion of compulsory optional components k into quantification of possible product configurations. In this case, let us have two stable components, one voluntary component and three compulsory optional components (i = 2, j = 1, k = 3, l = <1, 2>). Subsequently, we may calculate possible number of component combinations by the following formula:

$$\begin{aligned}\sum Conf &= \sum_{j=0}^{n}\left(\frac{j!}{n!(j-n)!}\right)\times\sum_{l=1}^{k}\left(\frac{k!}{l!(k-l)!}\right)\rightarrow\sum Conf\\ &=\left[\left(\frac{1!}{0!(1-0)!}\right)+\left(\frac{1!}{1!(1-1)!}\right)\right]\times\left[\left(\frac{3!}{1!(3-1)!}\right)+\left(\frac{3!}{2!(3-2)!}\right)\right]\\ &=2\times 6=12.\end{aligned} \tag{2}$$

Resulting number of product alternatives based on Eq. (2) above presents 12 possible product configurations. A summary algorithm to enumerate all possible product configurations is depicted in Fig. 2.

The following section will focus on the approach and methodology for enumeration of product alternatives respecting functional or design restrictions of future products.

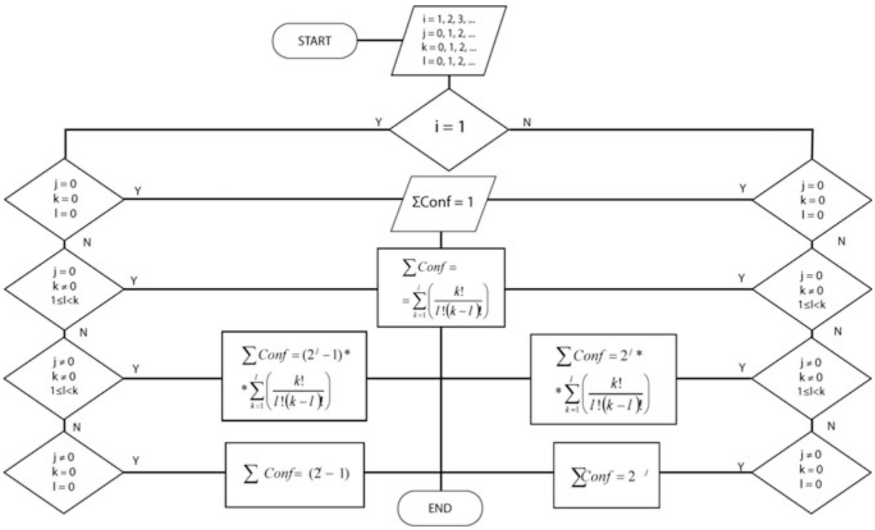

Fig. 2 Summary algorithm to enumerate all possible product configurations in MC

4 Description of Configuration Conflict Problem

In our approach, we focus on new solution of the specific problem easily applicable into a user-friendly managerial tool. The best way to describe proposed solution is through a realistic problem. For this purpose, we will adopt example for personal computer assembly by Yang and Dong (2012) where possible configurations with and without restrictions are identified (see Fig. 3).

In a simplified way, we will consider exactly four groups of components, namely Hard-disk (HD) units, Motherboards (MB), Central Processor Units (CPU) and Operating systems (OS). These groups consist of compulsory optional (CO) components or voluntary optional (V) components, respectively. The structure of all considered product components is graphically depicted in Fig. 3.

The first three groups (HD, MB, and CPU) contain additional specific selection rules. Then, the first step is a formulation of constrained conditions. Let us say there are seven restrictions related to (in)compatibility of components:

*R#*1—*CPU 486* must not be in the same configuration with *MB1*.
R#2—*MB2* must not be in the same configuration with PI and PII.
R#3—*CPU 486* must not be in the same configuration with motherboard *MB3*.
R#4—*OS1* must not be in the same configuration with *MB1* and *MB3*.
R#5—*OS2* must not be in the same configuration with *MB2* and *MB3*.
R#6—*MB2*, *MB3* must not be in the same configuration with *HD4*, *HD5*, *HD6*.
R#7— *OS2* must not be in the same configuration with *HD2* and *HD4*.

Subsequently, we depict an incidence matrix for all considered component restrictions $R_{1\text{-}7}$ (see Table 1). Then, it is possible to determine all feasible product configurations and generate their graphical models.

To enumerate number of restricted product configurations, the following procedure is proposed. Let us select e.g. group of HD units, for which we select arbitrary component from the group, e.g. HD2 that is one of the six HD unit options. Afterwards, we may construct an incidence sub-matrix for the HD2 option and group of CPU components. Because there is no restriction, HD2 as option can be combined with any CPU component (see Fig. 4a). Then we need to create three

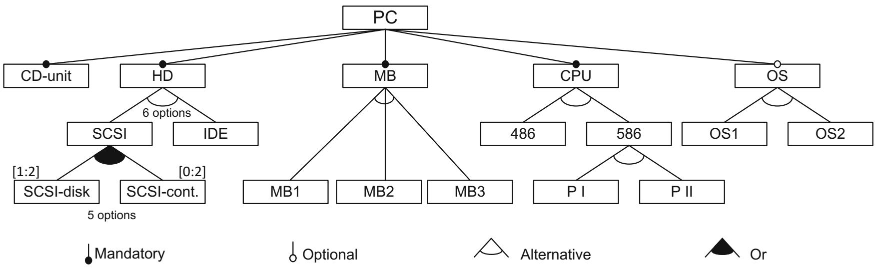

Fig. 3 Assembly model of a personal computer

Table 1 Incidence matrix for component restrictions $R_{1\text{-}7}$

		Group 1—HD						Group 2—CPU			Group 3—MB			Group 4—OS	
		HD1	HD2	HD3	HD4	HD5	HD6	P I	P II	486	MB1	MB2	MB3	OS1	OS2
Group 1—	HD1														
	HD2														7
	HD3														
	HD4											6	6		7
	HD5											6	6		
	HD6											6	6		
Group 2—CPU	P I											2			
	P II											2			
	486										1		3		
Group 3—MB	MB1													4	
	MB2														5
	MB3													4	5
Group 4—OS	OS1														
	OS2														

dimensional matrix relations between component HD2, group of CPU components and a group of MB components (step 2). Four restrictions are identified and accordingly CPU components can be combined with compatible MBs (see Fig. 4b). Note, that personal computer configuration without OS is also possible due to restrictions on OS2. Then, only one configuration with HD2 may include OS2 (see Fig. 4c). Finally, four-dimensional matrix of relations is constructed to determine number of restricted product configurations with HD2.

This sub-procedure depicted in Fig. 4 has to be repeated for the rest of components from the Group 1, based on which we obtain in total 21 all possible restricted product configurations (see Fig. 5).

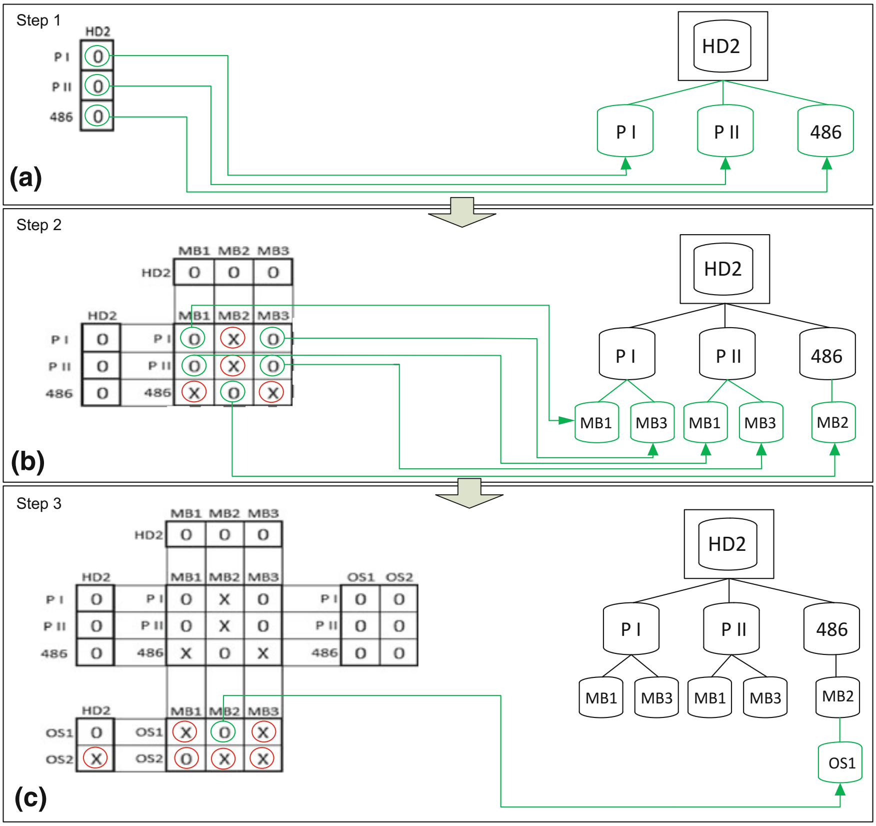

Fig. 4 Procedure for transforming incidence matrix for component restrictions into product component structure containing initial component HD2

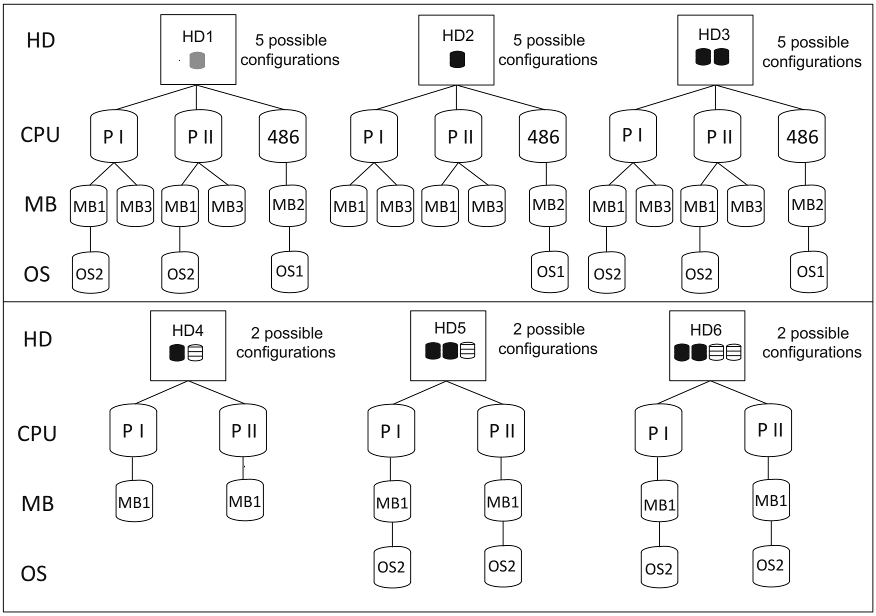

Fig. 5 All possible product designs of personal computer (21 options)

5 Summary

Presented approach and the method to resolve so called Constraint satisfaction problem offers new possibilities to bridge theoretical models to operational solutions. This approach allows subsequent application of tools for determination of variety induced complexity in mass customized manufacturing, which is frequently discussed in connection with a balance between the complexity and the usability. Variety induced complexity is the matter of interest especially when product designers have to solve so called constraint satisfaction problem (CSP). Using this tool, managers are able to identify precisely the extent of offered variety considered to be a crucial element of manufacturing complexity. This means we can directly use the outputs of the method for such purposes. Future research in this field should firstly focus on the proper use of product configuration number as a basis for systems design complexity measurements. Subsequently, verification of the systems complexity measurement should be provided on a more complex assembly model.

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Forecasting Dynamics of Daily Commuting to Work to Other Municipality in the Case of Changing Taxation Policies

P. Janež, S. Drobne and M. Bogataj

Abstract The forecasting of dynamics of trips to work is an important indicator for planning transportation in regions. The impact of changing property taxation on daily commuting of human resources is studied here using normalised and extended gravity model with the acronym NE_SIM. The taxation model is included in the NE_SIM gravity approach. The results for Slovenia are presented as a case study. The regression analysis of the linearized model implemented in Slovenia shows the following: if the property tax in the biggest city would increase so that the difference between interest rate and taxation rate would fall from 3% to 1% while other parameters would not change, then the daily commuting would increase by nearly 24%. The same approach can be used for forecasting the changes of in-flows in any spatial unit of a certain state, which would enable better planning of inter-municipality's transport infrastructure and logistics.

Keywords Housing rent · Value of real estate · Gravity model · Commuting · Taxation

1 Introduction

The forecasting of dynamics of trips to work is an important indicator for the spatial planners responsible for transportation planning and for the enterprises responsible for regional logistics. In the past, the ever-changing technologies considerably affected the directions and extent of migration flows (Bogataj and Drobne 2005).

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Such changes were also caused by the onset of the 2008 recession, which has had major implications for the labour market, as shown in Table 2 (Drobne 2014). Like Spain, Slovenia, an open national economy, has also been strongly affected, which quickly reflected in the labour market with rising unemployment rates and changing structural characteristics of the labour market. The Organisation for Economic Co-operation and Development (2009) reported that, suddenly, in 2008 the real Gross Domestic Product (GDP) growth rate in the majority of EU Member states started to decline. Commuting can be considered as a substitute to migration if work and residence are geographically separated, but it can be also considered as a complement if a person and family chooses to move away from their own or partner's workplace locality, and then commutes to work on a daily basis (Lundholm 2010). The latter is one of the main causes of suburbanisation. If there are conditions that allow (day-to-day) commuting, people often choose to commute instead of moving. And vice versa: poor commuting conditions can be perceived as a prerequisite for moving (Lundholm 2010; Drobne 2014). Property taxation is one of the factors that influence the changes in daily commuting, generating trips to work, although this also depends on several other factors. In Slovenia a new law will soon go into effect regarding property taxation. Therefore, the influence of property taxation on the generation of trips to work was studied using the gravity model, where many economic and environmental factors were considered.

2 Introducing Taxation in the Gravity Model

2.1 The Gravity Model

The general spatial interaction model—SIM as developed by Cesario (Cesario 1973, 1974) was normalized and extended into a model used to analyze the impacts of property taxation on the attractiveness of a municipality like presented by Eq. (1)

$$C_{ij} = c(C)K(d(t)_{ij}^{\varepsilon(C)}\prod_{s\epsilon S} K(s)_i^{\gamma(s)}K(s)_j^{\delta(s)} \tag{1}$$

or by its linear form:

$$\begin{aligned}\log C_{ij} &= \log c(C) + \varepsilon(C)\cdot \log K(d(t)_{ij} \\ &+ \sum_{s\epsilon S}\left[\gamma(s)\cdot \log K(s)_i + \delta(s)\cdot \log K(s)_j\right]\end{aligned} \tag{2}$$

where notation C_{ij} is the number of daily commuters from municipality i to municipality j, $c(C)$ is the constant of proportionality of the commuting model, $K(d(t))_{ij}$ is the coefficient of the time-spending distance by car between the central places of the municipality of origin i and the municipality of destination j and the state average, and the exponent $\varepsilon(C)$ measures its power on a commuting flow.

Higher the absolute value of $\varepsilon(C)$—which is negative—the willingness to commute is lower. In (1) and (2) $K(s)$ is the coefficient of the analyzed factor $s, s \in \{P, Z, B, H, O, V\}$, in the municipality of origin i (emissivity factor or stickiness), or the coefficient of factor s influencing flows to the municipality of destination j (factor of attractiveness); the analyzed factors and/or their coefficients are explained in Table 1. The impacts of emissivity in the municipalities of origin, the attractiveness to flows in the municipalities of destination, and the impact of distances between the origin and the destination were estimated by the regression analysis estimating regression coefficients $\varepsilon(C)$, $\gamma(s)$, and $\delta(s)$, where $\varepsilon(C)$ is the measure of the power of distances on the flows, $\gamma(s)$ is the measure of the emissivity of the investigated factor s in the origin (also the measure of stickiness), and $\delta(s)$ is the measure of the attractiveness of factor s in the destination. The factors that were found as significant on the bases of linear regression analysis (2) are presented in Table 1. Therefore the general Eq. (1) can be written as

Table 1 The coefficients in the gravity model which significantly influence the flows of daily commuters of human resources

$K(d(t))_{ij}$	**The coefficient of the time-spending distance** by car between the municipalities i and j is the quotient of the time-spending distance between the municipalities of origin and destination, $d(t)_{ij}$, and the average time distance $M(d(t)_{ij})$ of all interactions between municipalities, $K(d(t))_{ij} = d(t)ij/M(d(t)_{ij})$
$K(P)$	**The coefficient of population in a municipality** is the quotient between the population in the municipality i or j divided by the average number of inhabitants in all municipalities
$K(Z)$	**The coefficient of employment in a municipality** is the relative number of employed persons in the municipality
$K(B)$	**The coefficient of average gross personal income** in the municipality was calculated as the quotient between the average gross personal income divided by this relative number in the total area
$K(H)$	**The coefficient of the housing area per capita** is the quotient between the housing area per capita in the municipality divided by this relative number in the total analyzed area (state)
$K(O)$	**The coefficient of the municipality revenues per capita** is the quotient between the municipality revenues per capita divided by this relative number in the total analyzed area (state)
$K(V)$ **The coefficient of the average price per square meter of housing** space—the quotient between the average price per square meter of housing space in municipality j, and the average price per square meter of housing space in the total analyzed area (state): $K(V)_j = V_j/\bar{V}$. In the case that V_j increases to V_j^* where p_j% of inhabitants live and $(100 - p_j)$% of inhabitants live in other spatial units, while other factors remain the same, then the average in the total area increases to $\bar{V}^* = (p_j V_j^* + (100 - p_j)\bar{V})/100$	

$$C_{ij} = c(C)K(d(t)_{ij}^{\varepsilon(C)}K(P)_i^{\gamma(P)}K(P)_j^{\delta(P)}K(Z)_i^{\gamma(Z)}K(Z)_j^{\delta(Z)}K(B)_i^{\gamma(B)} \cdot K(B)_j^{\delta(B)}K(H)_i^{\gamma(H)}K(H)_j^{\delta(H)}K(O)_i^{\gamma(O)}K(O)_j^{\delta(O)}K(V)_i^{\gamma(V)}K(V)_j^{\delta(V)} \quad (3)$$

Equation (3) is describing that the intensity of daily commuting depends of all factors described in Table 1 and above it, with the powers $\varepsilon(C)$, $\gamma(s)$ and $\delta(s)$, which should be calculated by regression analysis of origin-destination flows between pairs of all municipalities which cover the total economic area.

2.2 Property Taxation Policies Influencing the Flows

Considering the economic effects of the local property tax, previous studies show that the economically meaningful way to specify the tax is a percentage of the market value (Mieszkowski 1972; Hamilton 1975). Here we shall study the tax on residential property and show the case study of Slovenia. This tax will be levied on property owners, but everywhere it is supposed to be shifted forward to tenants thus causing a decrease in housing demand due to the increase in commuting. Therefore we shall use the model that can be formalized as supply and demand curves and embedded to the gravity model of daily commuting. We shall consider the housing market in a set of regions with different taxation policies. The demand for housing is a demand for the servicing of housing in a given time period. The price of housing is the rent paid or the value of transaction of ownership. We shall consider that the price that is paid as housing rent is the amount that the tenant pays to the owner or that the homeowners pay implicitly to themselves. To ease the analysis, we shall assume that the number of available housing units is fixed. The equilibrium of demand and supply is at a higher quantity if the rent is lower. The market value of a unit of housing is the present discounted value of the stream of rents generated by the housing units considered. If the rent is considered at R per year, and if the yearly real estate tax as a percentage of market value is t, then the market value of property V can be calculated as

$$V(R,t,r) = \sum_i (R - tV)/(1+r)^i \quad (4)$$

In Eq. (4) r is the rate of discount and i gives summation over the number of years into the future. In our model, the rate of discount will be assumed constant where the average is assumed to be 4%, by the preference of the public for future income versus current income (the rate of time preferences). If the life of a housing unit goes to infinity, the relationship between the market value and the rent can be written as:

$$V = (R - tV)/r \Rightarrow V = R/(r - t) \quad (5)$$

In (5) $r - t$ is the capitalization rate. If t is 1% then $r - t$ is 3%. Our assumption is that if the taxation rate will be different in different regions, the flow of daily commuters will change because the proportions between real estate values will change. If the taxation rate changes equally in all regions, then it will not influence commuting flows. Therefore the changes in forecasting dynamics of trips to work, as an important indicator for planning transportation and logistics of flows between regions, can be calculated only when taxation policies depend on individual spatial areas (municipalities). Let us now introduce taxation in municipality j which it is not able to achieve higher rent, because people prefer to commute if the taxation increases only in this municipality! Namely, we also assume that only j introduce higher taxation. In case that V_j increases in the total economic area to V_j^* where p_j% of inhabitants live and (100-p_j)% of inhabitants live in other spatial units, while other factors remain the same, then the new average is $\bar{V}^* = (p_j V_j^* + (100 - p_j)\bar{V})/100$. The initial intensity of commuting flow to j

$$C_{\cdot j} = c(C)\sum_i K(d(t)_{ij}^{\varepsilon(C)} K(P)_i^{\gamma(P)} K(P)_j^{\delta(P)} K(Z)_i^{\gamma(Z)} K(Z)_j^{\delta(Z)} K(B)_i^{\gamma(B)} K(B)_j^{\delta(B)} \cdot K(H)_i^{\gamma(H)} K(H)_j^{\delta(H)} K(O)_i^{\gamma(O)} K(O)_j^{\delta(O)} K(V)_i^{\gamma(V)} (V_j/\bar{V})^{\delta(V)}$$

change to

$$C_{\cdot j}(t_j \neq 0) = c(C)\sum_i K(d(t)_{ij}^{\varepsilon(C)} K(P)_i^{\gamma(P)} K(P)_j^{\delta(P)} K(Z)_i^{\gamma(Z)} K(Z)_j^{\delta(Z)} \cdot K(B)_i^{\gamma(B)} K(B)_j^{\delta(B)} K(H)_i^{\gamma(H)} K(H)_j^{\delta(H)} K(O)_i^{\gamma(O)} K(O)_j^{\delta(O)} \cdot K(V)_i^{\gamma(V)} 100 \cdot V_j^*/(p_j V_j^* + (100 - p_j)\bar{V})$$

or simply the sum of all flows to j in the case of different taxation only in j is

$$C_{\cdot j}(t_j \neq 0) = C_{\cdot j}(t_j = 0)\left[100 \cdot V_j^* \bar{V}/(p_j V_j^* + (100 - p_j)\bar{V})V_j\right]^{\delta(V)} \quad (6)$$

3 The Case Study

Let us study the flow of daily commuters between Slovenian municipalities, awaiting a new law on real estate taxation to come into force. The first part of description of the case study which gives us the initial values of regression coefficients is reproduced from our previous work (Drobne 2014) and published with permission from Geodetski Vestnik. Table 2 show the intensity of these flows in a time series of 12 years, based on the national statistical data acquired from the

Table 2 The average daily commuting in Slovenia between municipalities

Year	No. of commuters (in 1000)	Annual growth rate	Year	No. of commuters (in 1000)	Annual growth rate
2000	240		2006	292	4.54
2001	246	2.38	2007	311	6.39
2002	251	2.17	2008	321	3.10
2003	260	3.56	2009	309	−3.77
2004	270	3.74	2010	306	−0.98
2005	280	3.55	2011	307	0.40

Table 3 The initial values of regression coefficients in log

	Power	std	t-value		Power	std	t-value
δ(C)	−3.5	0.02	−149	$\delta(H)$	1.02	0.13	7.8
$\gamma^{(p)}$	1.1	0.02	55	γ(O)	1.04	0.07	15
δ(P)	1.3	0.02	65	$\delta(O)$	1.43	0.07	20.9
γ(Z)	−0.53	0.06	−8	γ(V)	−0.17	0.04	−4.1
$\delta(Z)$	0.66	0.06	10	$\delta(V)$	0.453	0.042	10.9
γ(B)	−0.26	0.13	−2				
$\delta(B)$	0.81	0.13	6	N	R2	ANOVA F	ANOVA p
γ(H)	1.59	0.13	12	43,890	0.489	3235	0

Model (2)[a]

[a]*published with permission from Geodetski Vestnik.:* Drobne (2014)

"SI-Stat Data Portal" of the Statistical Office of the Republic of Slovenia (SURS 2015). These are data on population, employment, gross earning, useful floor space of dwellings, and labour commuting. The data on inter-municipal labour commuting were acquired from the Statistical Register of Employment, which keeps the data on the place of residence and place of work of the persons in employment. The data on municipal budget were acquired from the Ministry of Finance of the Republic of Slovenia (MF 2012), and the data on the average price of dwellings in the municipality were acquired from the Database for Mass Appraisal of Real-Estates of the Surveying and Mapping Authority of the Republic of Slovenia (GURS 2012). The data on time-spending distances between the municipal centres of Slovenia were calculated in the geographical information system ArcMap using data on state roads in Slovenia (DRSC 2013). Time-spending distances were calculated as travel times by car considering the state road system and the public road toll system in each analysed year.

We can see the increasing yearly growth till 2007, then a sudden decrease in 2008, followed by negative values in the next 2 years (Drobne 2014).

The impacts of the analysed variables on labour commuting between Slovenian municipalities (exponents) and other statistics showed in Table 3 were obtained in SPSS 21.0 using OLS method. The linearization (2) gives the values of the first regression coefficients presented in the Table 3. Let us now assume that the maximum capitalization rate will be set at the level of 3% and that each municipality will be able to decrease this value by additional taxes.

Now we consider what would happen if only municipality j (let us say the capital of Slovenia, Ljubljana, whose housing stock is approximately a quarter of the total housing stock in Slovenia—and regarding average $\bar{R} : R_j = 1.5\bar{R}$) set its capitalization rate at 1%, while others stayed at 3%. Based on the data of national statistical office on number of daily commuters between municipalities (SURS 2014) and the regression analysis of values $\varepsilon(C)$, $\gamma(s)$ and $\delta(s)$, appearing in Eqs. (1) and (2), we obtained the results in Table 3. From (5) and Table 3 it follows

$$\begin{aligned}C_{.j}(0.01) &= C_{.j}(0.03)\left[100 \cdot V_j^* \bar{V}/(p_j V_j^* + (100 - p_j)\bar{V})V_j\right]^{0.453} \\ &= C_{.j}(0.03)\left[10^4 \cdot R_j \cdot (\bar{R}/0.03)/((25R_j/0.01 + (100-25)(\bar{R}/0.03))R_j/0.03)\right]^{0.453} \\ &= C_{.j}(0.03)\left[0.5 \cdot 10^6 \bar{R}^2/10^4 \bar{R}^2 \cdot (25(1.5+1) \cdot 0.5\right]^{0.453}\end{aligned}$$

therefore

$$\begin{aligned}&C_{.j}(r - t = 1\%)/C_{.j}(r - t = 3\%) = \left[K\left(V_j^* = R_j/0.01\right)/K\left(V_j = R_j/0.03\right)\right]^{0.453} \\ &= \left[10^4 \cdot 1.5\bar{R} \cdot (\bar{R}/0.03)/(25(1.5\bar{R}/0.01) + (100-25)(\bar{R}/0.03))1.5\bar{R}/0.03\right]^{0.453} \\ &= \left[0.5 \cdot 10^6 \bar{R}^2/(10^4 \bar{R}^2 \cdot 25(1.5+1) \cdot 0.5)\right]^{0.453} = 1.6^{0.453} = 1.237\end{aligned}$$

If property tax in Ljubljana would increase so that $r - t$ would fall from 3% to 1% while other parameters would not change, then daily commuting would increase by nearly 24%.

4 Conclusion

The normalized extended SIM (NE_SIM) model can be used for forecasting the intensity of daily commuting and changes of flows when the real estate taxation policy is changed. In the approach presented here we show how to evaluate the expected flows of human resources when some parameters, i.e. those that significantly influence flows, change. We focused on the change of property tax policies, because this is currently one of the most discussed topics in Slovenia. But the same approach can be used when we evaluate the impact of other parameters. Moreover, we can suppose that the parameters are changing simultaneously, knowing the probability of their dynamics; this knowledge and the simulation model based on these principles could provide insight into potential development of daily commuting between municipalities, regions, or even states. From here we can estimate the thresholds required for spatial and logistics support.

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Public-Private Partnerships for Trade Facilitation: A Theoretical Model

M.L. de Campos, C. Morini, G.H.S.M. de Moraes and E. Inácio Jr

Abstract Trade Facilitation (TF) is a response to the observed growth in international trade over the last few years. Part of the solution to today's problems has been provided by Public-Private Partnerships (PPPs). This type of partnerships became known as one of the alternatives to increasing the effectiveness of investments and improvements. Since TF involves a relation between public and private agents, alternatives to solutions within the international trade field fall on this kind of partnerships. However, simply establishing a relation between both agents does not insure that all the benefits of TF will be reached. The objective of this research is to propose a theoretical model which can contribute to the measurement of the factors which mostly influence TF oriented PPPs. Such model derives from the theory of PPPs and presents a relationship matrix between Critical Success Factors (CSFs) and the perceived/expected performance of a TF oriented PPP. The relationship between each variable and the performance of a partnership was tested in order to quantify its strength. In order to validate the proposed theoretical model, we use the Structural Equation Modeling (SEM) method. The research is dedicated to answering the following research problem: which factors influence the success of TF oriented PPPs the most? Data was gathered both at national and international level, focusing on professionals from the private and public sectors and academia that either work with TF within their regular functions, or have an understanding about it. Results have shown that the variables of "macro-environment", "micro-environment" and "abilities of parties" presented, in that order, the most influence over TF oriented PPPs.

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1 Introduction

Trade facilitation (TF) can be explained as the application of methods for the reduction of barriers which can hinder trade. Its overall objective is to increase the flow of goods, services and people across international borders without compromising the security of this process or the ability of governmental agencies (mostly customs) of charging taxes and collecting revenue (Moïsé 2013).

Since these programs represent an interaction between private businesses and governmental agencies, and because there is a strong commitment established between both parties, they form a public private partnership (PPP). Although classic PPPs are mostly turned towards the provision of infrastructure, some are established having the provision of a service as its goal. In the international commerce field, this particular kind of PPP is seen as a customs-business partnership (CBP), and shares the advantages and risks of classic PPPs.

This study's objective is to propose and validate a theoretical model which is able to measure the main factors affecting the performance or success of a TF oriented PPP. Such model draws from the theory of public-private partnerships and presents a relationship model between critical success factors (CSF) and the perceived/expected performance of a PPP. The goal is to test the relation between each factor and the performance of a partnership, quantifying the strength of such relations by use of the Structural Equation Modeling (SEM) method.

Literature appears to present no use of SEM to analyze trade facilitation subjects, such as the performance of TF oriented PPPs. Overall, there is no attempt to create a validated model for measuring PPP performance in TF. The originality of this work is to contribute to a theoretical model that assesses the performance of PPPs in the TF context.

2 Literature Review

International Trade is made by the interaction between economic operators and border administrations, both immersed in an environment filled with national and international rules and regulations. Within this environment, Trade Facilitation (TF) has been drawing the attention of scholars, governments and the international trade community, despite not being a relatively new theme on this field. In its core is the concern for the operational quality of commerce, being firmly rooted "in the frustrations experienced by businesses when moving goods across borders" (Grainger 2014, p. 1167). In simple terms, trade facilitation (TF) can be explained as the application of methods for the reduction of barriers which can hinder trade. Its overall objective is to increase the flow of goods, services and people across international borders without compromising the security of this process or the ability of governmental agencies (mostly customs) of charging taxes and collecting revenue.

Governments and businesses can form partnerships for the development of a given project, which combine their mutual interests. This also happens on the customs and international trade field. Some of these Public Private Partnerships (PPP), as they are called, are TF oriented, and can be found inside the conventional PPP universe.

Public-private partnerships (PPPs) are a long term contract between a private and a public party for the provision of public services or goods. In this type of relation the private initiative takes upon itself most of the risks involved in the project, since it assumes the role of the government in providing that specific public service to the population (Lopes and Caetano 2015).

Knowing that not all partnerships are for providing infrastructure, and that some can be oriented toward services, a special type of PPP can be found among those and is the focus of this study: the customs-business partnership (CBP). A CBP is a type of relationship, built between a government and private initiatives, for reducing transaction costs and the need for constant interventions on the process of moving goods across borders, while not loosening the security standards imposed by customs. In that sense, it can be seen as a specific type of PPP which describes the singular partnership between a business and border authorities for trade facilitation purposes. Therefore, it is a trade facilitation oriented PPP.

3 Work Methodology

This research approaches the matter of TF oriented PPPs by assessing its performance. As a mean to measure performance in a quantifiable way, the Structural Equation Modeling (SEM) method was elected, since it has the ability of relating latent and observed variables via use of statistical tools (MacCallum and Austin 2000; Kohn et al. 2011; Svensson 2012). But, in order to use the SEM method, first a theoretical model should be built, one that explains the relation between such variables.

By looking at TF from the perspective of the PPP theory, the first logical step was to find the main factors which explain the success of such partnerships, in order to understand what affects PPP performance. Such elements are known throughout literature as critical success factors (CSF), and can be found on several papers.

From reviewing the PPP literature (with special emphasis to the work of Osei-Kyei and Chan 2015) a number of CSF were found. After focus groups with experts from private and government sectors, the result was a model which related CSF-based constructs to the perceived/expected performance of a TF oriented PPP and a questionnaire. Based on the final model, the first draft of a questionnaire was elaborated. The questions were divided into five large groups, representing the constructs, than classified according to the dimensions they belonged to.

The goal was to capture these experts' opinion of the model and measure the applicability of the questionnaire, all based on their knowledge and day-to-day experience with international trade. The sample included professionals from multinational companies, trade offices, public agencies and the Brazilian tax and revenue authority, Receita Federal do Brasil (RFB). All of them are deeply engaged not only with their daily routine in international trade. This background and variety is what made these professionals eligible for conducting the review of the questionnaire.

Many good results emerged from this round of validation for two main reasons. First, the comments of different experts converged on some questions, which promoted a fine tuning of the questionnaire. Second, their overall opinion about the questions was extremely positive. Some even mentioned the questionnaire was "covering it all".

Figure 1 shows the final version of the PPP performance model:

Based on this model, Table 1 presents the study's hypothesis.

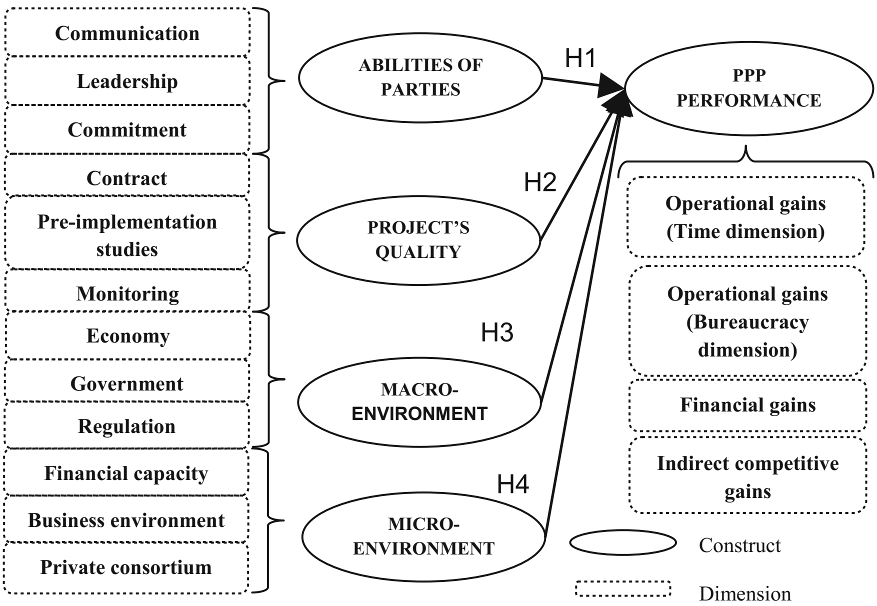

Fig. 1 Final version of the PPP performance model

Table 1 Study's hypotheses

Hypotheses	Description
H1	The abilities of the parties involved in a PPP have a positive influence over its performance
H2	The PPP project's quality has a positive influence over its performance.
H3	The macro-environment has a positive influence over the performance of a PPP
H4	The micro-environment has a positive influence over the performance of a PPP

4 Results

In order to define the minimum sample size for the research, the G*Power software, v3.1.9 was utilized (Faul et al. 2009). The result showed that 108 responses to the questionnaire were needed in order to effectively validate the model within an acceptable margin of error of 5%. The research was able to gather 118 responses, thus exceeding the proposed quota.

Data collection involved sending the online version of the questionnaire to professionals from the three spheres of international trade (public sector, private sector and academia). The sample consisted of every type of professional involved in international trade that either had a clear understanding of TF or worked with TF within their regular activities. This involved customs, regulatory agencies, industry professionals, researchers, attorneys, brokers, freight forwarders, importers, trading companies and maritime agencies, thus making for a very diverse sample of respondents, both at national and international levels.

The software chosen for calculating and validating the statistical tests was SmartPLS v2.0 (Ringle et al. 2014). In order to analyze the significance of the charges obtained for every observed variable, the "bootstrapping" technique was utilized, which, according to Hair et al. (2005), is not based exclusively on an estimation of the model, but calculates estimates for parameters and their trust intervals based on multiple regressions. A re-sampling of 1000 samples was utilized. After further testing the model and its variables, the final result was obtained, and can be seen on Fig. 2.

From the 4 hypothesis proposed by this study, one was rejected: the PPP project's quality has a positive influence over its performance (H2). Within the construct of "project's quality" were the dimensions of "contract", "pre-implementation studies" and "monitoring". The reason why this hypothesis was not validated is because the coefficients for this construct did not fall within the desired parameters (namely the T-statistic and p-value). On the other hand, TF programs are based on a compliance-certification logic. Such programs are designed having in mind a series

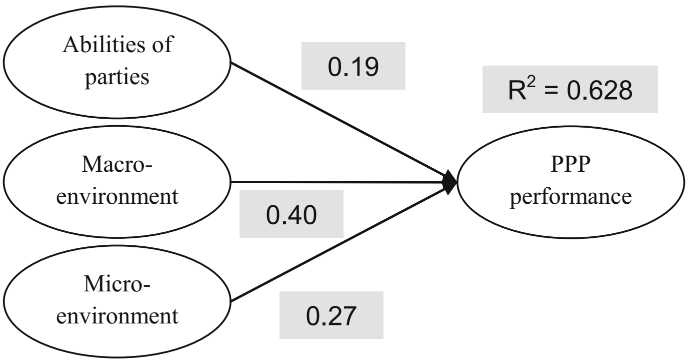

Fig. 2 Discriminate validity and structural model validation

of guidelines for customs, governments and businesses to undertake in order to get certified and recognized by other certified authorities. Since a company that wishes to be certified by a TF program has to follow a specific set of rules within a previously structured program, it is not a surprise to see that the project's quality is not among the confirmed hypothesis, for all the participants within such program do not have to decide on its design.

As for the hypotheses that were validated by the statistical tool, the "macro-environment" showed the strongest relation to TF oriented PPPs performance (coefficient of 0.40). In it are the dimensions of "economy", "government" and "regulation". From these, government and regulation provided the best questions for measuring this construct, with the latter providing questions with the highest factorial charges, such as "a stable regulatory mark contributes to the consecution of rights and guarantees to partnerships".

The second most influential construct to the performance of TF oriented PPPs was the "micro-environment" (coefficient of 0.27). In it were the dimensions of "financial capacity" (of the private sector), "business environment" and "private consortium". The general idea behind those factors is the coordination of the private sector towards the engagement of businesses to a TF culture. Therefore, initiatives which promote TF programs, such as workshops, meetings and other events can have an effect over the adhesion of companies to such programs. Furthermore, the financial capacity of businesses is also an important factor, for it affects their capability of meeting all of the investments required for implementing a TF program.

The still significant, but least influential construct, was "abilities of parties" (coefficient of 0.19), which encompassed the dimensions of "communication", "leadership" and "commitment". The latter is among the most discussed CSFs in literature. Likewise, communication is also an important factor for PPPs in general, but within the trade facilitation field, it falls upon the "soft" dimension of trade, as opposed to the "hard" dimension (as discussed by World Trade Organization/OECD 2013).

As for the measurement of the PPP's performance, all dimensions that formed that construct provided questions with high factorial charges. Such dimensions were that of "operational gains in time", "operational gains in bureaucracy", "financial gains" and "indirect competitive gains".

5 Final Remarks

Since a model such as this has never been validate before, the strategy of this research was to create an initial concept of a model which explains what factors have the most influence over a TF oriented PPP. The reason for that was to roughly understand the major factors which had the most influence over PPPs, in order to create a "compass" that could lead to further research.

The data presented good results with a high explanation level (almost 63%), but although macro-environment, for instance, has been the single construct which most influenced the performance of a PPP, an assertion cannot be made that "government" and "regulation" are the most important elements within this construct while "economy" is not. The next adjustments to the model should focus on such constructs and expand the understanding of what inside the macro-environment has the most influence over performance, thus breaking down the bigger construct into its component factors.

Regarding the questionnaire, ideally it should not contain as much questions as it does, for the response rate can drop because of this. However, since the idea of this research was to try and consider the most factors it could under one single analysis, the decision was to go through with a lengthy questionnaire. The next step of this research will now consider this factor, especially because, from the 52 original questions, 26 had a satisfactory measurement power, thus streamlining the original list. Furthermore, the measuring tool for the performance of PPPs was the questionnaire. Further research should include other types of data, than just the respondent's opinion, to measure performance.

Another consideration must be made regarding the sample. Although the number of responses has exceeded the quota, and the heterogeneity of respondents made for a general overview of their opinion (which was the original intention), further research should focus on specific realities in order to try and measure specific variances in the perception of TF oriented PPP performance. The opinion of professionals can vary from country to country. Likewise, different sectors within the same country may have different views about the same subject, thus making for a richer, more complex reality to study and model. The ideal result would be one that could present the general factors affecting PPP performance as well as specific variances like geographical region, work sector, socio-economic structure, among others, but a research such as that would demand time, energy, and a well validated model to begin with. The contribution of the present research is to set the first steps toward reaching such a model.

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Capacitated Lot-Sizing and Scheduling Problem for Second-Tier Suppliers in the Automotive Sector

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Abstract This paper extends Gupta and Magnusson's (Comput Oper Res 32:727–747, 2005) original proposal for the single machine Capacitated Lot-sizing Scheduling Problem (CLSP) with sequence-dependent setup costs to adapt it to a second-tier supplier in the automotive sector. We propose an extended mixed-integer program for the single machine CLSP that addresses raw material requirements and inventories, stock coverages, holding space limitations and overtime costs. Our proposal also contemplates scheduling plans with demands defined in units and capacities defined in units per period, which is very common in the automotive sector. Finally, a real-world description of the problem is considered as the basis of this work, although the validation model is carried out with a simple numerical example of Gupta and Magnusson (Comput Oper Res 32:727–747, 2005).

Keywords Inventory control, production planning and scheduling · Operations research · Industrial and applied mathematics for production

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1 Introduction

Second-tier suppliers in the automotive sector are evolving to more efficient production and scheduling plans in a similar way to their first-tier suppliers' evolution did from the mid 1990s to the early 2000s in a lean supply context. Thus, second-tier suppliers are now looking for optimal production and scheduling plans that satisfy demand from first-tier suppliers by minimizing raw material and finished goods inventories and overtime costs. Second-tier suppliers are characterized by maintaining stock coverages in a limited space within their facilities. In this paper, we extend the original CLSP work by Gupta and Magnusson (2005) and improved by Almaba-Lobo et al. (2008), by adapting it to the new requirements of a second-tier supplier in the automotive sector. These requirements are related to: (i) the lean supply of raw materials from third-tier suppliers, (ii) the consideration of stock coverages, (iii) the overtime costs, (iv) the space limitations and (v) the definition of quantities to produce in units. The rest of the paper is organized as follows. Section 2 presents a literature overview about CLSP contributions. Section 3 describes the CLSP problem in the second-tier supplier of the automotive supply chain. Section 4 proposes the model formulation and describes it. In Sect. 5, an illustrative example is proposed. Finally, Sect. 6 provides the main conclusions and further research.

2 Literature Review

Gupta and Magnusson (2005) provide an exact formulation of the CLSP with sequence-dependent setup costs and non-zero setup times, plus the additional feature that setups can be carried over from one period to the next, and that setup is also preserved over idle periods. Almada-Lobo et al. (2008) add a new set of constraints to the Gupta and Magnusson's (2005) model in order to avoid disconnected subtours. Fandel and Stammen-Hegene (2006) deal with the multi-level lot sizing and scheduling problem for job shop production in capacitated, dynamic and deterministic cases. For more detailed reviews of CLSP, we refer readers to Zhu and Wilhelm (2006), Jans and Degraeve (2008) and Buschkühl et al. (2010). More recent works on the CLSP are oriented to: industrial processes (Sarin et al. 2014); machine availability constraints (Ramezanian et al. 2013); lead-time considerations for the multi-level capacitated lot-sizing problem (Almeder et al. 2015), among others. Regarding large bucket models dealing with the general lot-sizing problem as an alternative to introduce sequence-dependent changeovers in the CLSP formulation, readers are referred to Fleischmann and Meyr (1997). We can conclude that the work by Gupta and Magnusson (2005) is one of the most cited papers on CLSP approaches, which justifies its selection as a reference model. We also note that no previous works have extended the Gupta and Magnusson's (2005) model in terms of raw materials supply, stock coverages, holding space limitations, and overtime considerations, which is the main objective of this paper, along with meeting scheduling plan requirements for a second-tier supplier in the automotive sector.

3 Description of the Problem

We consider a representative second-tier supplier in the automotive sector that produces injection automotive parts. The injection process is carried out through 18 injection machines with different molds by part. Currently, these injection machines are planned in an independent way and then the total number of mold changes are checked and adjusted when necessary. The main concern of second-tier supplier is to optimize the mold changes by minimizing the setup times. First-tiers provide weekly demand releases, from which the second-tier generates a daily Material Requirement Planning (MRP). The demand variability is a common pattern in the automotive sector, and second suppliers deal with this variability by using 3 days of stock coverages for finished goods; therefore, holding space limitations constraints would be required. The master planning calculates the lot-sizing based on the raw material prices, demand and setup times, to minimize the number of molding changes. The company works 24 h from Monday to Friday, although weekend overtime could be considered. Therefore, this point the problem consists of hourly production scheduling by calculating when the injection process per machine initiates and finishes by minimizing molding changes, inventories costs and overtime costs, but by meeting all demand, stock coverages and holding space limitations. Moreover, second-tiers not only transfer monthly requirements of raw materials to their suppliers, but also daily delivery orders are generated. Our proposal implies considering the Gupta and Magnusson's (2005) model as the basis of our CLSP by extending it with the following concerns: overtime production in order to avoid infeasibility by available capacity constraints; stock coverages and holding space limitations to avoid backorders; raw material delivery plans and inventories to extend the lean supply to third-tier suppliers in the automotive supply chain. Weekly demand is expressed in units and available capacities are defined by hours.

4 Model Formulation

In this section, a mixed integer programming formulation for CLSP, based on Gupta and Magnusson (2005) with the proposed extensions, is described (see Table 1 for nomenclature).

Table 1 Nomenclature

Index	
I	Set of products (finished goods and raw materials)
J	Set of finished goods
T	Set of periods
Parameters	
ts_{ij}	Setup time from product i to product j
c_t	Production capacity during period t
$INVMAX_i$	Available inventory capacity for product i
d_{it}	Demand of product i during period t
INV_{i0}	Initial inventory of product i
SR_{it}	Scheduled receptions of product i during period t
b_{ji}	Quantity of i to produce a unit of finished good j
tp_i	Required time to produce a unit of product i
cs_{ij}	Setup cost from product i to product j
ci_{it}	Inventory cost of product i during period t
co_t	Overtime cost during period t
cv_i	Penalty for soft inventory constraint violation for product i
M	Big number
N	Number of finished goods
Decision variables	
X_{it}	Amount of i to produce during period t
Y_{it}	1 if product i is produced during period t, 0 otherwise
S_{ijt}	1 if a setup occurs from product i to product j during period t, 0 otherwise
INV_{it}	Inventory level of product i at the end of period t
Q_{it}	Amount of product i to order to suppliers
TOV_t	Overtime hours during period t
α_{it}	1 if product i is produced *first* during period t, 0 otherwise
β_{it}	1 if product i is produced *last* during period t, 0 otherwise
γ_{it}	1 if machine is setup for product i at the end of period t, 0 otherwise
ω_t	Strictly positive when at least one product is produced in period t, 0 otherwise
δ_t	0 if exactly one product is produced during period t, an unrestricted non-negative number otherwise
V_{it}	Auxiliary continuous variable to eliminate disconnected subtours
H_{it}	Auxiliary variable to generate soft inventory constraint for product i during period t

Objective function

$$Min\, z = \sum_i \sum_j \sum_t cs_{ij} \cdot S_{ijt} + \sum_i \sum_t ci_{it} \cdot INV_{it} + \sum_t co_t \cdot TOV_t + \sum_i \sum_t cv_i \cdot H_{it} \quad (1)$$

Constraints

$$INV_{i,t-1} + X_{it} - INV_{it} = d_{it} \quad \forall i \in J, t \tag{2}$$

$$INV_{i,t-1} + SR_{it} + Q_{it} - INV_{it} = \sum_{j} b_{ji} \cdot X_{it} \quad \forall i \in \{I\} \backslash \{J\}, \text{t} \tag{3}$$

$$INV_{i,t} \leq INVMAX_i \quad \forall i, t \tag{4}$$

$$INV_{it} + H_{it} \geq d_{i,t+1} \quad \forall i \in J, t \tag{5}$$

$$X_{it} \leq M \cdot Y_{it} \quad \forall i \in J, t \tag{6}$$

$$\sum_{i \in J} tp_i \cdot X_{it} + \sum_{i \in J} \sum_{j} ts_{ij} \cdot S_{ijt} - TOV_t \leq c_t \quad \forall t \tag{7}$$

$$Y_{it} \leq \omega_{it} \quad \forall i \in J, t \tag{8}$$

$$\sum_{i \in j} Y_{it} - 1 \leq (N-1)\delta_t \quad \forall t \tag{9}$$

$$\omega_t \leq \sum_{i \in j} \alpha_{it} \leq 1 \quad \forall t \tag{10}$$

$$\omega_t \leq \sum_{i \in j} \beta_{it} \leq 1 \quad \forall t \tag{11}$$

$$\alpha_{it} \leq Y_{it} \quad \forall i \in J, t \tag{12}$$

$$\beta_{it} \leq Y_{it} \quad \forall i \in J, t \tag{13}$$

$$\alpha_{it} + \beta_{it} \leq 2 - \delta_t \quad \forall i \in J, t \tag{14}$$

$$\sum_{i \in j} \gamma_{it} = 1 \quad \forall t \tag{15}$$

$$\sum_{j} S_{jit} \geq Y_{it} - \alpha_{it} \quad \forall i \in J, t \tag{16}$$

$$\sum_{j} S_{ijt} \geq Y_{it} - \beta_{it} \quad \forall i \in J, t \tag{17}$$

$$S_{ijt} \geq \gamma_{i,t-1} + \gamma_{jt} - \omega_t - 1 \quad \forall i \in J, \; i \neq j, t \tag{18}$$

$$S_{jit} \geq \alpha_{it} + \gamma_{j,t-1} - 1 \quad \forall i \in J, i \neq j, t \tag{19}$$

$$S_{ijt} \geq \beta_{it} + \gamma_{jt} - 1 \quad \forall i \in J, \ i \neq j, t \tag{20}$$

$$V_{jt} \geq V_{it} + N \cdot S_{ijt} - (N-1) - N \cdot \gamma_{i,t-1} \quad \forall i \in J, \ i \neq j, t \tag{21}$$

$$0 \leq \omega_t \leq 1 \quad \forall t \tag{22}$$

$$X_{it}, INV_{it}, Q_{it}, TOV_t, V_{it}, H_{it}, \delta_t \geq 0 \quad \forall i, t \tag{23}$$

$$S_{ijt}, Y_{it}, \alpha_{it}, \beta_{it}, \gamma_{it} \in \{0, 1\} \quad \forall i, j, t \tag{24}$$

Objective function (1) minimizes all the performed setups, inventory holding and overtime costs, and the penalty of finished goods inventory coverage violations. Constraints (2) and (3) are typical inventory balance equations for finished goods and raw materials, respectively. Constraint (4) limits the inventory level for each product according to the available inventory capacity. Constraint (5) corresponds to inventory coverage extension for finished goods, what is very common in the automotive upstream supply chain. In this case, and in order to avoid infeasibilities, it is set as a soft constraint with a penalty cost included in the objective function. Constraint (6) ensures that whenever $X_{it} \geq 0$, decision variable Y_{it} is set at 1. Constraint (7) establishes the production capacity limits by taking into account possible overtime decisions. According to Gupta and Magnusson (2005), Constraints (8)–(15) determine which product is produced first and last during a given period. They also find the product for which the machine is setup at the end of each period. In constraint (8), ω_t is forced to be 1 if any item is produced during period t. Constraints (10) and (11) ensure that α and β are 1 for exactly one product during a given period, if production occurs during that period. Constraints (12) and (13) ensure that α and β are set at 0 during idle periods when no finished good is produced. If only one product is produced during a period, then values α and β must equal 1 for that product and 0 for all the other products. This also forces δ to be 0 in Constraint (14). However, if more than one product is produced during a period, then δ becomes positive by Constraint (9). In this case, Constraint (14) ensures that if the α value for a product is 1, then the corresponding β value is 0, and viceversa. Constraint (15) establishes that only one product can be setup at the end of each period. So Constraints (9) and (14) imply that when more than one product is produced during a single period, the same product cannot be produced both first and last during a period. Constraints (16) and (17) apply whenever more than one product is produced during a single period. They force at least one S_{ijt}'s to be 1 per product *i*, except when this product is either the first or the last product in the sequence. Constraint (18) forces a setup during production-free periods when the machine's setup state at the end of the period is not the same as the setup status at the end of the following period. Constraints (19) and (20) are needed to properly count the setups between the periods during which the machine is not idle, while

Constraint (21) ensures the subtours elimination according to Almada-Lobo et al. (2007). Finally, Constraints (22) to (24) correspond to the binary and non-negativity properties of the decision variables.

5 Numerical Example

In this section, the formulation of Eqs. (1)–(24) is tested in a small data set. The model was implemented with a high level language for mathematical programming, using MPL v5.0. The illustrative example was solved by the Gurobi solver. The example data are as follows: three finished goods are to be scheduled over the three considered periods. Each finished good is manufactured from its corresponding raw material. The matrix used for the bill of materials (b_{ji}), setup cost (cs_{ij}) matrix and the demand (d_{it}) matrix are presented below:

$$b_{ji} = \begin{pmatrix} 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \quad cs_{ij} = \begin{pmatrix} \infty & 1 & 2 \\ 1 & \infty & 1 \\ 5 & 5 & \infty \end{pmatrix} \quad \mathrm{d_{it}} = \begin{pmatrix} 10 & 10 & 10 \\ 25 & 30 & 20 \\ 0 & 60 & 40 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

Setup times are the same for all the machines ts_{ij} = 1.2 h. Production capacity c_t = 24 and it is determined in hours of available production. The required time to produce a product i, tp_i = 0.24 is also provided in hours. The data related with the inventory is summarised in Table 2. The CLSP model is considered for a single machine. For this numerical example, it is assumed that this machine is initially setup for product type 1, so that α_{11} = 1. The model also plans the reception of raw materials used to manufacture finished goods. The initial scheduled receptions of raw materials for all the periods is SR_{it} = 0. This example also considers overtime before or after regularly scheduled working hours in order to meet the demand without backorders. Regarding the overtime cost, it is estimated in co_t = 100 currency units per hour. Finally, penalties for maintaining the stock level of finished goods below the demand level during the following period, are considered through cv_i = 100 monetary units.

Table 2 Inventory data

Inventory data	INV_{i0}	*0*	*0*	*0*	*0*	*0*	*0*
	$INVMAX_i$	15	25	55	15	25	55
	ci_{it}	10	10	20	7	8	6
Inventory levels	$INV_{it=1}$	*10*	25	*55*	*0*	*0*	*0*
	$INV_{it=2}$	10	20	40	*0*	*0*	*0*
	$INV_{it=3}$	10	20	40	*0*	*0*	*0*

INV Inventory, *INVMAX* Maximum Inventory

Using this data set the following production schedule is obtained and the corresponding inventory levels are shown in Table 3. Period $t = 1$: ($X_{11} = 20$), ($X_{21} = 50$), ($X_{31} = 55$) (setup carry-over for $i = 3$). Period $t = 2$: ($X_{32} = 45$), ($X_{22} = 25$), ($X_{12} = 10$) (setup carry-over for $i = 1$). Period $t = 3$: ($X_{13} = 10$), ($X_{23} = 20$), ($X_{33} = 40$). The corresponding inventory levels are shown in Table 2. The inventory levels for products 2 and 3 at the end of the first time period are lower than the corresponding demand levels for these items during period 2, because the maximum inventory capacity for these products is lower than these demand levels. In this case, modelling the inventory coverage as a soft constraint allows model infeasibilities to be avoided. The results obtained for the decision variables that enable these soft constraints are $H_{21} = H_{31} = 5$. A total of 8.4 h of overtime is needed to meet demand during the first period. The value of objective function value is 5500 currency units.

6 Conclusions

This paper has adapted the CLSP model by Gupta and Magnusson (2005) to a second-tier supplier in the automotive sector in order to optimize the lot-sizing by minimizing setup, inventories, overtime costs, penalties for unfulfilling stock coverages and satisfying demands, considering holding inventory space limitations. A raw material delivery plan is generated besides existent MRP plans for extending lean supply to third-tier suppliers. The model has been tested by using a numerical example inspired by Gupta and Magnusson's (2005) previous study. Further research would be conducted to mainly validate the model with real-world data from the automotive second-tier supplier. Managerial implications would be related to integrating this model into the company Enterprise Resource Planning (ERP) and to the use of a cloud platform that contemplates the running of the model (Lauras et al. 2015). The integration of all single-machine scheduling plans into a single model considering the total molding changes is another research possibility. Balancing of the raw material consumption within the production sequence would be an interesting extension of the model. Finally, other constraints could be easily added, such as overtime limitations, labor consumption, alternative packaging and setting the number of molding changes per shift or day.

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A Generic Decision Support Tool for Lot-Sizing and Scheduling Problems with Setup and Due Dates

Cristovao Silva, Nathalie Klement and Olivier Gibaru

Abstract Decision support tools are essential to help in the management of industrial systems at different levels: strategic, to design the system; tactical to plan activities or assign resources; operational to schedule activities. In this paper, we present a generic and modular decision support tool to solve different planning, assignment, scheduling or lot-sizing problems. To the best of our knowledge, such generic tool does not exist. The methodology is illustrated by solving a real world lot-sizing and scheduling problem from a plastic injection company.

Keywords Decision support tool · Scheduling · Lot-sizing · Injection moulding

1 Introduction

Nowadays, industry is changing. We are in the fourth industrial revolution. Industrial system has to be more and more intelligent and flexible. It has to be more intelligent to anticipate a shortage of raw materials, a maintenance operation or an emergency command. It can be more intelligent thanks to the internet of objects. It has to be more flexible to adapt itself to the future commands. It could be more flexible thanks to a tool which would model different new configurations of the company and evaluate the consequences of the potential changes.

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Our main purpose in this article is to present a decision support tool which can be used in many industrial cases at different levels, thus allowing increasing company flexibility. This decision support tool can be used to plan activities and assign them resources according to several constraints. In this paper, we illustrate how the proposed tool can be used at the tactical level: which resource can do each activity and when; and at the operational level: determine the schedule of activities assigned to each resource. At this level, it could also consider emergencies, like arriving jobs that have to be done as soon as possible. But it could also be used at the strategic level: according to activities which have to be done in a horizon planning, how many resources do we need?

The proposed tool is composed by a generic module, which can be used in several different problems, and three specifics steps conducted according to the considered problem. Thus, the proposed tool can support the decision process for several different planning problems with a minimum development work. The method used by the tool is a hybridization of a metaheuristic and a list algorithm. The metaheuristic can be used without any changes and the list algorithm needs to be adapted according to the studied problem.

The general method is described in Sect. 2. Section 3 specifies the problem considered in this paper to test the tool. The list algorithm developed to solve the proposed problem is given in Sect. 4. The different results are presented in Sect. 5. Then, the paper ends with the main conclusions and proposed further work.

2 Method: Hybridization of a Metaheuristic and a List Algorithm

The proposed tool uses a hybridization of a metaheuristic and a heuristic, more precisely a list algorithm, see Fig. 1. A single solution based metaheuristic or a population based metaheuristic can be used. The encoding used by the meta-heuristic is a list Y of jobs. In the single solution based metaheuristic case, the neighbourhood system is a permutation of jobs. The list algorithm considers the jobs according to their order in list Y to schedule and assign them to the required resource, considering the problem constraints. This builds the solution X. The objective function H evaluates the solution X. According to this evaluation, the solution is chosen or not by the metaheuristic. At the end of the running, the given

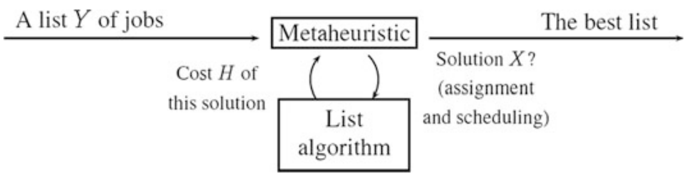

Fig. 1 Hybridization metaheuristic—list algorithm

solution by the hybridization is the best list of jobs: the one which optimizes the objective function by applying the list algorithm.

This hybridization can be used to solve many problems: the specificity of a given problem is only considered in the list algorithm. Three steps need to be specified according to the studied problem:

- Problem specification: definition of the constraints and objective function of the problem, presented in Sect. 3.
- List algorithm: developed according to the problem specification. The list algorithm proposed to solve the problem considered in this paper is presented in Sect. 4.
- Generation of instances: data of the problem are used to characterize the jobs and to implement the list algorithm, presented in Sect. 5.

3 Considered Problem

The proposed tool was already used to solve a hospital activities planning and resource assignment problem (Klement 2014). The current paper deals with the use of the same tool to solve a lot-sizing and scheduling problem found in a plastic injection company, previously described in Silva and Ferreira (2004), thus showing its ability to be adaptable to several different problems.

The problem presented in this paper has been motivated by a production planning and scheduling problem faced by a company that produces small plastic parts for the electric/electronic industry. The products are obtained by injection moulding, a process in which a polymer is heated to a plastic state and forced to flow into a mould cavity, where it solidifies. The moulded part is then removed from the cavity. The process produces components that are almost always net shape. Thus, injection moulding is typically a single-stage manufacturing process where a number of products are manufactured on shared machines with their respective tools. The mould is the main tool used in the injection moulding, being custom designed for a given part to be produced. In each cycle the injection machine close the mould, inject melted plastic into the cavity, open the mould and eject the plastic part.

The company considered in this paper manufactures a wide range of products, injected in more than 500 different moulds, owned by the clients, but managed by the company. To satisfy the costumers' orders, the company must plan the execution of more than 300 production orders per week. The company shop-floor is composed by 25 injection moulding machines. Once a week, the production planner considers all the orders to be produced (characterized by the quantity of items to be produced and the required due date) and define a production plan for the next week, allocating them to the available machines and defining the sequence by which they have to be produced.

The problem can be stated as follow: A set of n jobs has to be scheduled on shared machines with their respective mould. Each job has a given size, which determines its processing time, and an associated due date. A sequence dependent setup time is required when the production changes over from a job requiring a given mould to a job requiring a different one. A job is not allowed to be split but several jobs, requiring the same mould, may be grouped together to form one lot and, thus, saving setup costs. Due to compatibility factors, each mould can only be allocated to a subset of the available machines. Each mould is unique; thus the same mould cannot be allocated to different machines during the same time period. The objective is to allocate jobs to each available machine and define the processing sequence in each machine in order to minimize the total tardiness.

The problem described previously can be seen as a lot-sizing and scheduling problem. A small literature review about this kind of problems is given below.

One definition of lot-sizing problem can be the following: given a number of jobs to process and a number of available machines, the objective is to determine the best size of lots of items, to assign them to the machines and to schedule them. The problem can be single-item, or multi-item. It can be single-level, if jobs need to be processed by one machine; or multi-level, if they need to be processed by several machines consecutively. The demand can be static or dynamic. The planning horizon is divided into periods, called time-bucket, which can be big or small. In big bucket problems, a period is long enough to produce multiple items. In short bucket problems, time period is so short that only one type of item can be produced in each time period (Gicquel et al. 2008). Drexl and Kimms (1997) makes a chronology of existing lot-sizing problems. A recent review of lot-sizing problems is done in Copil et al. (2016).

The problem described in this paper is a particular case of the lot-sizing problem which considers big time-buckets, called Capacitated Lot-Sizing and Scheduling Problem (CLSP). The CLSP is defined by a planning horizon (finite or infinite), a number of levels (single-level or multi-level), a number of jobs, some capacity or resource constraints, the demand (static or dynamic), and the setup structure (simple or complex if setup costs or times are sequence dependent) (Karimi et al. 2003).

Since in our problem we have parallel machines and a given job can only be allocated to a restricted number of machines, due to mould/machine compatibility constraints, two approaches can be considered.

The first approach consists in considering the shop-floor composed by a set of unrelated machines: the job processing time is either the one given if the machine can use the needed mould, or infinite otherwise. In their literature review about lot-sizing and scheduling problems with sequence-dependent setup, Zhu and Wilhelm (2006) distinguishes identical machines (processing time of a job on a machine depends only on the job), uniform machines (processing time depends only on the job and the speed of the machine to which it is assigned) and unrelated machines (processing time depends both on the job and the machine to which it is assigned). Around eighty articles are referenced in the literature review, but only seven of them considered unrelated machines.

Lot-sizing problems with unrelated machines are NP-Hard (Anderson et al. 1997), thus most papers use approach methods to solve it. Ozdamar and Birbil (1998) developed hybrid heuristics involving search techniques such as simulated annealing, tabu search and genetic algorithms to deal with the capacitated lot-sizing and loading problem. Kimms (1999) developed genetic algorithms to solve the multi-machine lot-sizing and scheduling problem, considering some scarce resources, but the main assumption is that at most one setup can occur per period. Weng et al. (2001) proposed several heuristics to solve the problem of scheduling independent jobs on a set of unrelated parallel machines with sequence dependent setup times. Kim et al. (2002) used simulated annealing to solve a similar problem but in which items of one job can be split among several machines. Meyr (2002) proposed some methods to solve simultaneously the lot-sizing and scheduling problem with non-identical machines. Dastidar and Nagi (2005) also solved the unrelated machines case in a plastic injection application, with resource constraints, using a two-phase strategy. Toledo and Armentano (2006) used a Lagrangian-based heuristic to solve capacitated lot-sizing problem involving the production of multiple items on unrelated parallel machines. Generally, the developed methods are quite sophisticated.

Another way to consider our problem consists in seeing the shop-floor as being composed by a set of identical machines with eligibility: a machine can be eligible to process a job if the mould used by the job can be used on this machine. Lot-sizing and scheduling problems with respective solving methods, with parallel machines and eligibility constraints, have been considered by Ruiz and Maroto (2006) and Xiao et al. (2015).

Our approach is to consider the plastic injection problem as a CLSP with finite planning horizon, big buckets, single-level, multi-items, capacitated resources, static demand, complex setup structure and parallel identical machines with eligibility.

4 The Proposed List Algorithm

List scheduling algorithms are one-pass heuristics that are widely used to prescribe schedules. The standard list scheduling algorithm constructs a schedule by assigning each job according to their order in the list to the first machine that becomes idle (Zhu and Wilhelm 2006). Some list algorithms have been proposed in Klement (2014) to solve the problem of activities planning and resources assignment in the hospital case. We propose a new list algorithm to schedule jobs for the proposed injection moulding problem, see Fig. 2.

The proposed list algorithm is combined with a single solution based meta-heuristic, the stochastic descent, to form the method described in Sect. 2. In the next section, the results obtained by the proposed method are compared with the results obtained with a two stage heuristic presented in Silva and Ferreira (2004).

```
For all the jobs in the list,
    Order the machines according to their release date
    First machine
    While the job is not assigned
        If the job and the machine are compatible
            If the needed mould is available
                If the actual used mould on the machine is the good one
                    Actualize the release date of the machine without setup
                Else
                    Actualize the release date of the machine with setup
                Assign the job
            Else
                Assign the job to the machine which uses the needed mould
                Actualize the release date of that machine, taking into account the setup if needed
        Next machine
```

Fig. 2 List algorithm for the injection problem

5 Results

To test the proposed tool, company historical data were collected and used to randomly generate instances of several sizes: 3 instances with 3 machines (16, 18 and 20 moulds; 47, 53 and 57 jobs, respectively); 3 instances with 5 machines (25, 26 and 26 moulds; 81, 80 and 79 jobs) and one instance with 10 machines (59 moulds and 177 jobs). Jobs processing time follow an exponential distribution with an average of 10.75 h and due dates were generated using a uniform distribution ranging between 24 and 312 h. Setup times consider the time to dismount the current mould (ranging between 15 and 45 min) and to mount the next one (ranging between 20 and 60 min).

Table 1 presents the results obtained for each instance size with the heuristic proposed in Silva and Ferreira (2004) and with the proposed tool. Comparison considers the average tardiness and average number of setups among all instances of a given size.

The results show that the developed tool is effective. An average reduction of 25% of tardiness is achieved. For some instances the reduction of tardiness is up to 50%. Nevertheless, the proposed method leads to an increase in the number of setups. It is important to note that, since the main objective of the company was to reduce the tardiness, the number of setups was not considered in the objective function of the proposed method. For other problems, an objective function

Table 1 Results

Instance	Silva and Ferreira (2004)		Our proposal	
	Aver. tardiness	Aver. setup	Aver. tardiness	Aver. setup
3 machines	68.6	21.6	53.6	35.3
5 machines	212.9	32.7	98.3	45.7
10 machines	1020	82	964	114

considering tardiness and number of setups, with different weights, can be envisaged. Silva and Ferreira (2004) used a two-phase algorithm: first it assigned moulds to machines, and then it schedules jobs on each machine. So it was not possible to assign one mould on several machines at different times. In this way, the proposed method is less constraining which explains the better results.

The proposed method is easy to develop and gives good results. For small instances, 3 and 5 machines, results are achieved in a small computational time; a few minutes. For larger instances, the computational time required to attain a good solution increase and can reach a few hours. That is why for the instance with 10 machines, the proposed methodology doesn't conduct to an improvement as high as the ones found for smaller instances. To reduce the time required to reach good solutions for large instances more efficient metaheuristics, like simulated annealing, are being coded. We expect that, with these metaheuristics it will be possible to solve industrial size problems (20 machines and approximately 300 jobs) in a reasonable amount of time.

6 Conclusions

In this paper, we present a generic decision support tool which can be used to solve several different planning problems with a minimum development work. The application of this tool is illustrated with a real world lot-sizing and scheduling problem, from a plastic injection company, considering sequence dependent setup time, unrelated machines or identical machines and machine eligibility, for multi-items at single level. Results show that the proposed tool can be effectively used to solve the proposed problem, promoting better results, in terms of tardiness, than a two-stage heuristic developed for the same problem in the past. The tool is considered generic because it is easily adaptable to a large range of problems, simply by coding adequate list algorithms.

Several paths can be considered for future development for this work. We intend to code new metaheuristics for the proposed method: other single based solution as simulated annealing or iterated local search, or population based metaheuristics like particle swarm optimization. This will allow assessing the effectiveness of the proposed tool under different metaheuristic approaches. For the case of the problem described in this paper, we intend to develop a mathematical model and use optimization tools to solve it for small instances (since the problem is NP-hard), thus comparing the proposed tool results with optimum ones.

We also intend to develop new list algorithms for different industrial problems. Right now data are being collected in two companies with lot-sizing and scheduling problems. One consists of a Discrete Lot-sizing and Scheduling problem and the other consists of a Continuous Lot-sizing and Scheduling problem with multi-stages. Then, we intend to develop new list algorithms for different scheduling, planning or assignment problems presented in the literature for which instances are known. Ultimately, we will be able to have a tool with a generic part composed by a metaheuristic and a library of list algorithms, which will allow a rapid implementation for different companies, facing different problems.

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Part III
Logistics

Application-Oriented Optimization of Internal Milk-Run Systems

Andreas Martini, Tobias Mauksch and Ulrich Stache

Abstract The optimization of already designed, real Milk-run Systems has hardly received any attention in the scientific literature yet, despite its substantial potentials. The hereinafter presented method allows for the first time the individual evaluation of Milk-run Systems by means of a system of performance indicators, the automatic sensitivity analysis of the input variables and the systematic optimization by means of a decision tree procedure. By using a modular MS Excel-Tool, a fast and comprehensible identification of the optimization paths is possible. A case study illustrates the potential benefits of the method and the tool for the user.

Keywords Milk-run · Tugger train · Optimization · Material supply · Production supply

1 Introduction

The increasing spread of the “forklift-free production” concept for internal transports has led to Milk-run Systems more and more replacing forklift trucks as means of transport (Emde 2011: 2). One key reason for this change is the reduction in number and seriousness of accidents (DGUV 2013: 70; Emde 2011: 74). Further advantages of Milk-run systems are the higher load capacity (Baudin 2004: 53) and the resulting reduced demand for vehicles, personnel and energy (Meinhardt and Schmidt 2012: 58; Müller 2014: 23).

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The tendency of using Milk-run Systems has brought the planning and optimization of such systems as a research task into the focus of several considerations (Alnahhal et al. 2014; Martini and Stache 2015). The procedures developed for this purpose can be classified as associated with Operations Research or Production Engineering. The approaches of the first-mentioned sector focus on the development of methods, the practicable result, however, is subordinate. Generally, these procedures model delimited subproblems by using complex mathematical systems of equations and solve them by special heuristics and algorithms (e.g. Emde 2011; Ciemnoczolowski 2007; Golz 2013). The planning approaches in the Production Engineering sector use application-oriented procedures basing on design rules and simple calculations (e.g. Brungs 2012; Günthner et al. 2013; Droste 2013). The objective of all these approaches is to provide practicable procedures for generating functioning solutions. However, finding the global optimum is not the explicit objective of the procedures. The comparative observation of literature shows that the optimization of already designed resp. existing Milk-run Systems has hardly received any attention from an application-oriented point of view, despite its substantial potential (Martini 2015: 12).

2 Objectives

The overarching objective of this research project is the development of an application-oriented, model-based approach for the optimization of internal Milk-run Systems considering individual objectives. Requirements on the method regarding the functionality to be covered can be specified by decomposing the overarching objective in subobjectives. The method shall…

- …enable the user to depict a real Milk-run System in a model basing on actual data and analyses (e.g. process times and transport quantities) and evaluate it in regards of economical, logistical and qualitative criteria.
- …allow an analysis of the depicted Milk-run System showing how parameter changes of input variables effect the target variables and which influence factors are relevant.
- …support the identification and application of promising optimization measures basing on the analyses results and asses their expected effect on the behavior of the real Milk-run system.

In this process particular requirements are made on generality, efficiency and flexibility of the method.

3 Method

The functional requirements on the method allow the formulation of an iterative solution approach consisting of three model-based modules (Fig. 1).

The model for depicting the Milk-run Systems for this method is based on the established technical and organizational design options (VDI 5586: Part 1, 2016). The generating of the model as well as the subsequent examinations are made by means of the spreadsheet calculation program Microsoft Excel, as it is widely used and provides the required functions for the calculations and analyses by default (e.g. VBA-Macro programming). A further advantage is an easy-to-realize modular structure which guarantees the clarity on one hand and the extensibility of the method and the tool on the other.

3.1 Depiction and Evaluation Model

Start point of the modeling is the definition of the actual state of the Milk-run System by selecting possible boundary conditions and design features. The depiction is made by means of morphologies as these illustrate the design diversity of Milk-run Systems and also clearly depict the system configuration. Then, the specific input data has to be entered into separate cells in the Excel sheets. This comprises for example the input of the route-specific data (e.g. route length) or the individual process times (e.g. loading time). As each calculation is made basing on the route, these entries are required for each route to be considered.

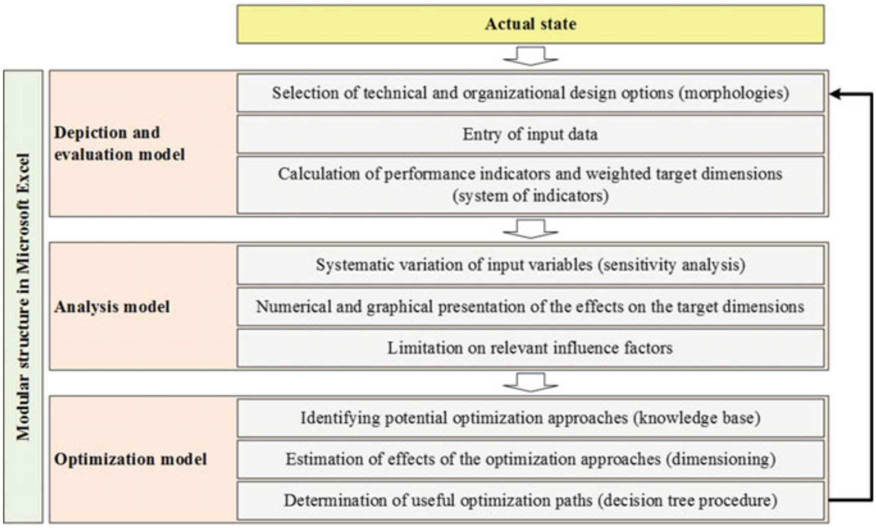

Fig. 1 Solution approach for evaluating and optimizing internal Milk-run systems

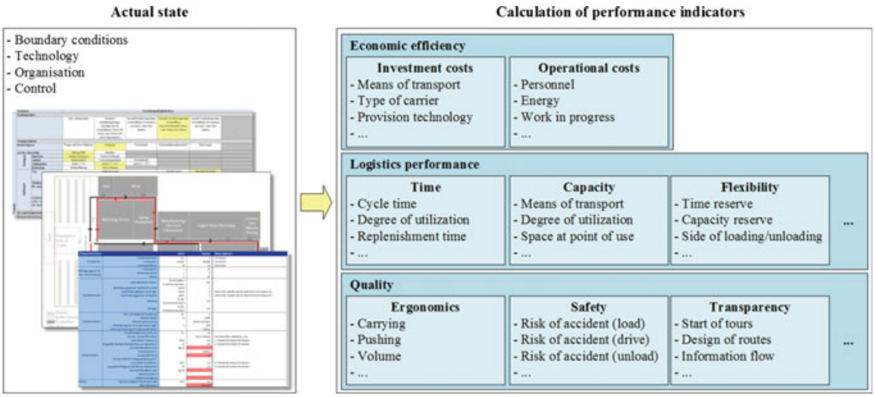

Fig. 2 System of indicators with target dimensions calculated basing on actual state input data

Basing on the individual input data, the calculation of the relevant performance indicators is made by means of a hierarchical system of performance indicators (Fig. 2). The performance indicators of the lowest level in the hierarchy are linked to resp. are correlated with each other and are associated to defined target dimensions (e.g. operational costs, time or ergonomics). Thus, an aggregation to top performance indicators with regards to the overarching objectives economic efficiency, logistics performance and quality is possible as well as the evaluation of the Milk-run System considering the user preferences. The depiction of the evaluation results is made in a performance indicator cockpit which route-specifically and comprehensively visualizes the performance indicators and levels of objective achievement.

3.2 Analysis Model

In the second step, the performance-limiting factors of the Milk-run System and the drivers of the target variables are determined by sensitivity analyses. While doing so, the input variables in the evaluation model are systematically varied and the respective effects on the target dimensions and their performance indicators are numerically and graphically displayed (Martini 2015). This is made "ceteris paribus" ("all other things being equal") as due to this, the modifications of a target variable can be traced back to the variation of only one parameter (cause-effect-correlation) (Martini et al. 2015: 66). The selection of the influence factors is based on the consideration which variables have an effect on the performance of the modeled Milk-run System. Finally, these are the input parameters influencing the time and capacity variables when dimensioning the Milk-run System. The cycle time as a main dimensioning parameter consists of the loading time, the hold times, the unloading time and the driving time. The relevant input parameters are the *loading time per load carrier (LC),* the *hold time per stop*, the *unloading time per LC* as well as the *route length* and the *average velocity.* The important capacitive restrictions of the Milk-run System are the *transport capacity of the tugger train* as well as the *number of buffers at the demand stations*. The robustness of the Milk-run System against transport demand fluctuations is depicted by the *throughput per route.*

For a specific application, the parameter characteristics to be varied are set. A sensitivity analysis is carried out, setting the minimal and maximal values of these variables by default to 50% resp. 150% of the initial value and thus allowing a comparison of the results. An individual adaption is possible. The steps are freely selectable, however, are normally 10% of the initial value. The sensitivity analysis within the evaluation model is carried out by means of VBA-Macros. The result is a matrix of the corresponding target variables for each observed variable. For supporting the user interpreting the results, the calculation of the so-called influence intensity (II) basing on the values of the target variables (TV) is carried out automatically. Here the influence intensity shows the percentage change of the target variable in regards to the initial value when changing the variable. This contributes to the standardization and comparability of different target variable dimensions. It is distinguished between the negative influence intensity when reducing the value of the variable and the positive influence intensity when increasing the value of the variable. This allows the identification of non-linear target value curve shapes. The influence intensity for a variable is calculated by using the following equations.

$$II_{variable,negative} = \frac{TV_{variable,actual\_state} - TV_{variable,\min}}{TV_{variable,actual\_state}} \tag{1}$$

$$II_{variable,positive} = \frac{TV_{variable,\max} - TV_{variable,actual\_state}}{TV_{variable,actual\_state}} \tag{2}$$

By means of these gradients depending on the input and the target variables, it is normally possible to assess whether the respective target variable curve shape is linear or non-linear. The target variable curve shapes are also depicted graphically for also assessing individually defined values of the variable. This allows a statement about the operating point of the Milk-run System as well as the specific influence intensity of the examined influence factors.

3.3 Optimization Model

In the optimization model firstly those design measures are identified which can have an influence on the relevant influence factors. The basics for this are the design alternatives of the depiction and evaluation model and a knowledge base containing the qualitative effects of measures on influence factors.

The next step is to assess whether the potential optimization measures really have the desired effect on the target valuables for this individual case. This has to be made as modifications in design do not necessarily have a singular influence on the input and target variables but complex interdependencies can exist (Martini 2015: 4). Thus, not only the structure of the Milk-run System but also its resource requirements have to be checked in order to avoid misinterpretations. As the examination is not expedient for the real system, the Milk-run System has to be redesigned and dimensioned. This is made within the scope of the depiction and evaluation model by using the application-oriented dimensioning approach of the VDI Guideline 5586 (VDI 5586: Part 2, 2016). Finally, expedient optimization paths are determined by comparing the planned variations with the actual state in regards of the individual objectives. By using the decision tree procedure, only those variations are considered which lead to an improvement. In turn, these variations can be used as new initial solutions (iterative improvement). The optimization is finished when no better solution can be found or when defined threshold values with regard to the modification of target variables cannot be achieved.

4 Case Study

The modeling and optimization is exemplarily depicted by a Milk-run System for empties supply and finished goods disposal by means of lattice boxes (lb) in a mechanical engineering company. In total, twelve different demand stations each with one stop are provided with empties from a central storage and the finished goods are transported from these demand stations to the same central storage. The lattice boxes are exchanged 1:1 at the demand stations. As a start condition five tugger trains on two routes each with 1320 m length are used for this transport task. There are three tugger trains on route 1 and two tugger trains on route 2. All tugger trains consist of one tug each with four trailers in E-type frame design. Loading and unloading is always from the left side.

4.1 Evaluation

Table 1 shows the evaluation result of the actual state by means of selected performance indicators for the routes and the complete system. The investment costs for the initial condition are not relevant in regards of economic efficiency as the technology applied already exists. However, the investment costs are recorded for calculating the investment-related operational costs (imputed interests and deprecations as well as maintenance and service costs). For the operational costs it is striking that a percentage of 86% are personnel costs. For the target dimension time it is striking that with 63% a large percentage of the cycle time is for the driving. The cause is the length of the route. In regards to the number of vehicles and

Table 1 Exemplary performance indicators of the case study system

Target variable	Unit	Route 1	Route 2	System
Operational costs	[€]	249.701	145.862	395.563
Percentage personnel costs	[%]	87	83	86
Travel distance per hour	[km]	8.25	4.62	12.87
Average cycle time	[s]	1.252	1.252	1.252
Percentage driving time	[%]	63.3	63.3	63.3
Average degree of utilization (time)	[%]	72	61	68
Number of vehicles (required)	[pcs]	2.17	1.22	3.39
Number of vehicles (rounded)	[pcs]	3	2	5
Average degree of utilization (capacity)	[%]	100	100	100
Number of drivers per day (required)	[pcs]	4.35	2.43	6.78
Number of drivers per day (rounded)	[pcs]	6	4	10
Assessment of ergonomics		Intermediate	Intermediate	Intermediate

deployed personnel it can be seen that in the overall view the number of actually used vehicles and deployed personnel is higher than the theoretically required demand. This is due to the fact that the vehicles and personnel are firmly assigned to the routes. The ergonomic evaluation basing on the "Leitmerkmalmethode" (LMM) achieves scores in the medium range, i.e. the individual stress perception of the personnel has to be identified and, if necessary, design measures have to be developed (BauA 2016: 1).

4.2 Analysis

The sensitivity analysis is made by using the test design shown in Table 2. The number of buffers is no performance-limiting factor for the study case as sufficient buffers are available at the demand stations. So this parameter is not further considered. In the following, the throughput factor is for evaluating the system regarding the robustness against fluctuations of throughput requirements.

Table 3 exemplarily shows the calculation results for the velocity variation of route 1. With 58.3% this parameter shows the highest influence intensity according to the amount in regards to the target variable operational costs. The negative sign in the table marks in each case the asynchronous correlation between the influence factor and the target variable, i.e., when reducing the average velocity by 50% the operational costs rise by 58.3%. In contrast leads the increasing of the average velocity by 50% to a reduction of operational costs by 21.6%. So it is obvious that there is a non-linear correlation between the input variable velocity and the target variable operational costs.

Figure 3 shows this correlation by a graphic illustration of the target variable curve shape. There is a regressing curve for the exemplary target variables

Table 2 Test design for the sensitivity analysis of the case study system

No.	Variable	Unit	Characteristic			Step size
			Min	Actual state	Max	
1	Load time per carrier	[s]	22.5	45	67.5	4.5
2	Hold time per stop	[s]	10	20	30	2
3	Unload time per carrier	[s]	22.5	45	67.5	4.5
4	Length of route	[m]	660	1.320	1.980	132
5	Average velocity	[km/h]	3	6	9	0.6
6	Transport capacity	[lb]	2	4	6	0.4
7	Factor of throughput	[%]	50	100	150	10

Table 3 Results for the influence intensity calculation of route 1 for varied average velocity

Target variable	Unit	Average velocity			$II_{vel,neg}$	$II_{vel,pos}$
		33	6	9	[%]	[%]
Operational costs	[€]	395.401	249.701	195.668	−58.3	−21.6
Percentage personnel costs	[%]	89	87	88	−63.3	−21.1
Travel distance per hour	[km]	8.25	8.25	8.25	–	–
Average cycle time	[s]	2.044	1.252	988	−63.3	−21.2
Percentage driving time	[%]	77.5	63.3	53.4	−22.5	−15.5
Average degree of utilization (time)	[%]	89	72	86	−22.4	18.4
Number of vehicles (required)	[pcs]	3.55	2.17	1.72	−63.3	−21.1
Number of vehicles (rounded)	[pcs]	4	33	2	−33.3	−33.3
Average degree of utilization (capacity)	[%]	100	100	100	–	–
Number of drivers per day (required)	[pcs]	7.10	4.35	3.43	−63.3	−21.2
Number of drivers per day (rounded)	[pcs]	8	6	4	−33.3	−33.3
Assessment of ergonomics		Intermed.	Intermed.	Intermed.	–	–

operational and personnel costs, i.e. the effect of the velocity on these target variables depends on the actual operation point of the Milk-run System (here: 6 km/h).

4.3 Optimization

The comparison of the influence intensities considering the influence direction shows that the route length for route 1 with an influence intensity of 30.8% and for route 2 with an influence intensity of 32% each represent the most important

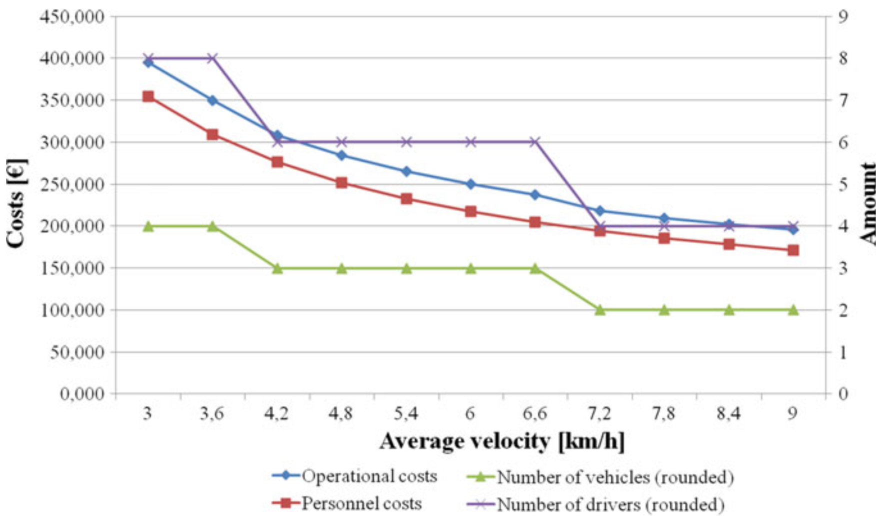

Fig. 3 Graphical presentation of target variables development for varied average velocity

influence factor (comparison of $II_{variable,positive}$). As a first step a shortening of the route length is recommended for an optimization. Potential optimization measures with such an effect are e.g. using a shortcut or splitting the routes. As the use of shortcuts with the present layout provides only little optimization potential, the measure of route splitting has to be checked. In this case study both routes are split so that there are two routes each with 1110 m length and two routes each with 520 m length for which the resource requirement is calculated and the result is evaluated (Table 4).

Due to the low resource requirement for the routes 3 and 4 (each 0.38 required vehicles), their one-to-one relationship between vehicles, drivers and routes is cancelled, i.e. they are provided by one driver with one vehicle on an alternating basis. The summarizing evaluation of the target state shows that the number of required vehicles and drivers per shift can be reduced from five to four by splitting the routes. Thus, operational costs are reduced by 18%. By splitting the routes, there are less cycles per hour necessary on these routes which reduces the travel distance per hour from 12.87 to 8.7 km. The driving time percentage is reduced from 63.3 to 49.7%. Despite the reduction of vehicles and personnel, the time utilization is nearly the same. Throughput fluctuations of up to 30% per route can be absorbed with these calculated resources. The number of pushing movements per staff member and shift slightly increases. However, the LLM-score and thus the assessment of the ergonomic load remains unchanged.

The case study shows a first step of a potential optimization path which, due to the comparison of evaluation performance indicators of the developed solution with the actual state, is assessed as promising and so will be pursued. Further optimization approaches as e.g. regarding loading and unloading from both sides or the

Table 4 Exemplary performance indicators of the redesigned case study system

Target variable	Unit	Route 1	Route 2	Route 3	Route 4	System
Operational costs	[€]	164.140	70.384	53.468	53.468	324.420
Percentage personnel costs	[%]	86	80	80	80	83
Travel distance per hour	[km]	4.95	1.93	0.91	0.91	8.70
Average cycle time	[s]	1.120	1.120	772	772	946
Percentage driving time	[%]	58.9	58.9	40.4	40.4	49.7
Average degree of utilization (time)	[%]	70	54	75	75	67
Number of vehicles (required)	[pcs]	1.40	0.54	0.38	0.38	2.70
Number of vehicles (rounded)	[pcs]	2	1	0.5	0.5	4
Average degree of utilization (capacity)	[%]	100	100	100	100	100
Number of drivers per day (required)	[pcs]	2.80	1.09	0.75	0.75	5.39
Number of drivers per day (rounded)	[pcs]	4	2	1	1	8
Assessment of ergonomics		Intermed.	Intermed.	Intermed.	Intermed.	Intermed.

automation of processes have to be examined according to the described procedure regarding their potentials and, if necessary, have to be considered as a permissible initial solution for the iterative optimization.

5 Conclusion

By means of the presented method already existing or planned Milk-run Systems can be analyzed, individually evaluated and improved in a target-oriented way. Thus, this method goes further than the common application-oriented planning methods which normally only generate one feasible solution. Unlike the structure-/problem-specific algorithmic optimization methods, there is a universal applicability of the method for all kinds of Milk-run Systems (LLC/SLC (Large Load Carrier/Small Load Carrier), supply/disposal, coupled/decoupled routes). Due to the modular structure the calculations are comprehensible and the models can be individually extended so that future research can build up on it. Even the transferability of the method to related problems like the optimization of order picking systems seems possible.

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Analysing the Fit Between Innovation Strategies and Supply Chain Strategies

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Abstract Drawing on the concept of strategic fit, this conceptual paper seeks to clarify the relationship between innovation strategies and supply chain management strategies. This work seeks to propose a conceptual framework to help advance research in this area. A literature review was conducted as a basis for developing a unified framework which best reflects the relationship and fit between the different strategies in each area, something which has been clearly under researched from the strategic fit perspective. The findings can be used to guide the decision making of managers in the areas of innovation and supply chain. Additionally, they can serve as a reference for helping coordinate with other areas of the business, in order to ensure the correct fit between activities and strategies.

Keywords Innovation strategies · Supply chain strategies · Fit · Alignment

1 Introduction

The introduction of corporate strategies and their application to the business are recognised as highly important factors in the search for competitive advantage. Strategy covers a wide range of areas within the business, and commonly, also includes concepts related to innovation and supply chain (SC) management, two areas of great importance to a company's competitiveness. At the same time, many

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of the problems and difficulties associated with the management of innovation (Anthony et al. 2006; Pisano 2015) and the supply chain (Fisher 1997; Qi et al. 2009) stem from the lack of clear strategies which define the objectives of these processes.

The importance of strategic fit, or just fit, is one of the oldest ideas in strategic management (Porter 1996; Venkatraman and Camillus 1984). Porter (1996) highlights the importance of fit for the success of a firm's strategies, stating that a lack of fit between activities leads to a failure to differentiate the strategy. As such, fit is seen as the adjustment of one variable in relation to another, in such a way that the combination gives rise to the best results (Donaldson 1987; Venkatraman 1989; Venkatraman and Camillus 1984; Wu et al. 2014).

Agreement has grown in the literature on innovation that the combination of internal and external sources of knowledge is a fundamental factor in the success of the chosen innovation strategy (Love et al. 2014; Veugelers and Cassiman 1999). At the same time, although the relationship between innovation and supply chains is relatively strict and it has been subject to considerable attention by researchers in recent years, the alignment between innovation and SC strategies is a relatively little studied area of the literature (Zimmermann et al. 2016).

Using the fit concept as a basis, this study seeks to clarify the relationship between innovation strategies and supply chain management strategies. Following from this, a conceptual framework is proposed, helping to contribute to the advancement of knowledge in this area and to the development of strategies for business.

2 Innovation Strategies and SC Strategies

Confronted with increasing competition in their target markets, firms from differing sectors and with differing styles typically include objectives linked to innovation in their strategic plans (Veugelers and Cassiman 1999). However, adopting innovation strategies is not yet a common practice among companies (Anthony et al. 2006; Guan et al. 2009; Pisano 2015) and receives relatively little attention in the academic world.

Some authors present classifications for innovation strategies based on characteristics that they consider important and differentiate them in this process. The model proposed by Clausen et al. (2012) considers five strategies: ad hoc; supplier based; market-driven innovation; R&D intensive; and science-based innovators.

Supply chain management, just like innovation management, is a common theme in corporate strategic plans for many organisations. However, while it is also recognised as a source of competitive advantage for organisations, firms do not always define their objectives with respect to the SC. Besides this, the topic has received little attention in the academic world (Qi et al. 2009; Qrunfleh and Tarafdar 2014; Sharifi et al. 2013).

The model proposed by Marshall Fisher in his important and influential article published in the Harvard Business Review in 1997 (Fischer 1997) led many authors to adopt two types of SC strategy: Lean—equivalent to the Efficient strategy of Fisher, and Agile—equivalent to the Market-responsive strategy of Fisher (Christopher and Towill 2002; Qi et al. 2009, 2011; Qrunfleh and Tarafdar 2014).

3 The Concept of Fit

For Venkatraman (1989), the concept of fit is a fundamental element for constructing theory in a wide range of different areas, including strategic management. Naman and Slevin (1993) state that understanding the concept of fit is fundamental for understanding the difference between the field of strategic management and other fields, such as finance, human resources and marketing.

Venkatraman and Camilus (1984) argue that, in accordance with the strategic theory that sees firms as open systems, strategy can be understood as the act of combining the different elements which make up the strategic mix of the company —internal, such as skills and resources, and external, such as opportunities and threats. In this scenario, this combination is known as fit.

In this study, fit is understood to be the adjustment of one or more variables—activities, strategies, business areas or organisations—relative to the others, such that the combination leads to improved results (Donaldson 1987; Venkatraman 1989; Venkatraman and Camillus 1984; Wu et al. 2014).

This concept is reflected in what Venkatraman (1989) defines as "fit as matching"; "This perspective is invoked for strategy concepts in which fit is a theoretically defined match between two related variables" (Venkatraman 1989, p. 431).

It is notable that while there are differences between the concepts of fit and alignment, many studies use the two concepts in a similar way. Alignment can be thought of as the effort made by organisations to ensure that their activities and strategies pull in the same direction in a synergistic way. At the same time, fit is understood as the result of the forces which align the variable involved.

The concept of fit has been studied over the years in different areas and contexts in the literature. Table 1 presents different approaches to the concept of fit in the literature.

4 Conceptual Framework

The way firms approach innovation and in their supply chains, as well as the strategies they embraced, impact on the performance of the processes and the organisation as a whole. According to the concept of fit, the fit between different variables in the firm—in this case, internally—can be a driver for optimising results.

Table 1 Examples of the how the concept of fit is used in the literature

Author/Year	Journal	Approach to fit
Henderson and Venkatraman (1990)	MIT Sloan Management	Analysis of the fit between the IT strategies and the corporate strategies
		Analysis of the fit between the firm and its environment, its strategies, structure or processes
Stock et al. (2000)	Journal of Operations Management	The fit between two related functions
Gonzalez-Benito (2007)	Journal of Operations Management	An analysis of the fit between purchasing strategies and corporate strategies
		The fit of the strategies in a specific area to the capabilities in the same area—understood as the effectiveness of the area in question
Kodali (2011)	Measuring Business Excelence	A study of the fit between SCM strategies and corporate strategies
Acur et al. (2012)	Journal of Product Innovation Management	Analysis of the different types of internal and external alignment, the influencing factors and the effects of fit on the process of developing new products
Wu et al. (2014)	International Journal of Production Economics	Study of the fit between the supply chain management strategies and the corporate strategies
Ryu et al. (2015)	IEEE Transactions on Engineering Management	Alignment between the service innovation strategies and the business strategies and their effects on the performance of the firm
Prajogo (2016)	International Journal of Production Economics	Fit between the firm's strategies (or one area) and the business environment for the firm

As such, the analysis which follows is based on the principle that the different combinations of strategies—innovation and SC—will lead to different results.

According to Clausen et al. (2012), the firms which are part of the ad hoc group invest little in research and development activities and they have no solid commitments to others (knowledge sources). As such, these firms have slower learning paths and, given that this strategy produces relatively little innovation, the firms are less able to invest the profits from previous innovation in the next round of innovative activity (Clausen et al. 2012). Firms which depend mainly on their suppliers as a source of knowledge for innovation belong to the group of supplier-based strategy (Clausen et al. 2012). Adopting this strategy can be seen as an incremental approach to innovation where the firms do not invest a large amount of internal resources in innovation.

The Lean strategy seeks to create efficient supply chains, in terms of costs, focusing on a reduction in lead times and an elimination of the stock waste. This strategy fits well with stable and predictable demand and products that change little

(Christopher and Towill 2002; Qi et al. 2009, 2011; Qrunfleh and Tarafdar 2014). The main objective of an SC Lean strategy is to reduce costs and increase efficiency by eliminating waste, both in the internal processes and the external processes of the organisation (Qi et al. 2009). This, this can be seen to be most consistent with the ad hoc and supplier-based strategies.

On the other hand, firms which adopt a market-driven innovation strategy have their innovation focus centred on the customer and look for knowledge from industry sources, such as competitors and customers (Clausen et al. 2012). As such, firms seek out this type of relationship and they invest a high level of resources in the innovation process.

The Intensive R&D strategy is adopted by firms which tend to have a wide range of objectives and innovation sources, while being especially focused on internal and external R&D processes (Clausen et al. 2012). This strategy favours the development of radical innovations and increases the learning capacity of the firm. The approach requires continual effort and attentiveness from the supply chain, or in other words, characteristics associated with the Agile strategy type.

Firms with Science-based innovation strategies are highly dependent on scientific knowledge sources, such as patents, and the relationship with universities and research institutes as part of their innovation process. Firms in this group tend to be persistent innovators—measured by the number of organisations which innovate, given that they have more or less ability to innovate again in subsequent periods—with basic science offering great technological opportunities (Clausen et al. 2012). This type of strategy also requires a response from the supply chain.

An Agile SC strategy, in turns, seeks to guarantee the flexibility and adaptability of the SC given the constant changes in the needs of the customers and the competitive environment, using rapid, dynamic and continuous responses (Christopher and Towill 2002; Qi et al. 2009; Qrunfleh and Tarafdar 2014). The objective of this type of strategy is to devise products which are focused on the needs of the customer (customer-driven products) with unique characteristics for the market, so that the competitive advantage is retained in constantly changing environments. The reduction in the life cycles of the products leads to an increase in pressure on the SC as a whole to provide products and services in a more rapid and responsive way (Qi et al. 2009). This SC strategy seems to fit better with the last three innovation strategies. Figure 1 shows the conceptual framework which reflects the relationship between the strategies.

5 Implications and Conclusions

The framework that has emerged from this work can be used as a reference by managers for decision making in terms of adopting innovation and supply chain strategies. Additionally, it can be used as a way of encouraging the alignment between these and other areas of the business, helping with the fit between activities and strategies. The study shows that knowledge of the reality of other functions in

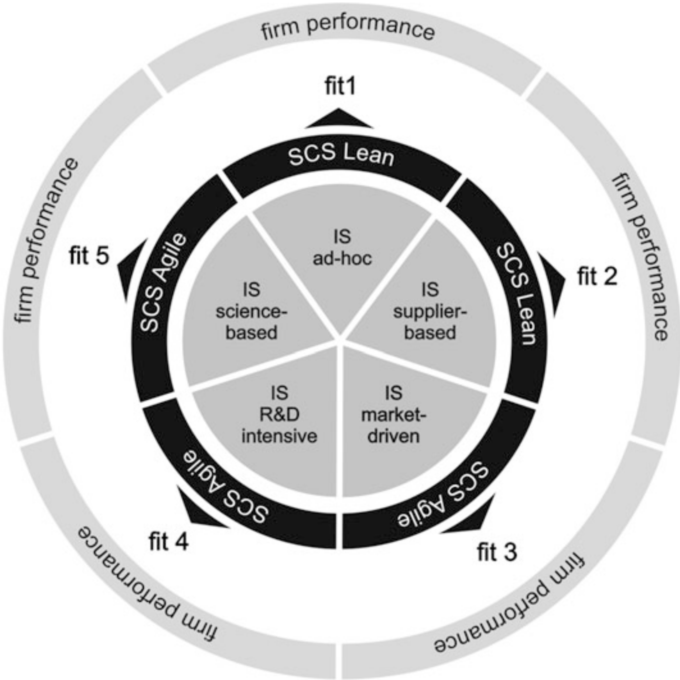

Fig. 1 Conceptual framework

the business—with the same true of external partners—it is possible to make better adjusted decisions, making it possible to achieve better results.

We conclude that not only should the definition of corporate strategies be a collective process, but that the definition of the strategies in the different areas and functions should also be carried out in a collective and collaborative way.

Many studies point to direct evidence that the complementarity between internal evidence—in general the internal activities of R&D—and the external access to knowledge represent a fundamental factor for the innovation process (Love et al. 2014; Veugelers and Cassiman 1999). The alignment between the innovation and SC strategies also leads to an improved fit between the internal activities of the firm and the activities of the partners. This is because the adopted SC strategy helps to orientate the selection and the definition of the way relationships work with the other actors in the chain, including the channels for exchange of information and knowledge.

We highlight the fact that the strategies, as shown in this work, are dynamic processes in constant evolution. Changes in the approach of the firm towards innovation should always lead to a re-evaluation of the SC strategies. The opposite is also true; in other words, changes in the way the supply chain works or in the SC strategies can necessitate changes in the way the firm manages innovation.

Considering the complexity of the environmental contexts, the processes and the firm's products, we also concluded that different strategies can coexist within the same organisation—both innovation and SC—depending on the products and markets. As such, it is also possible that a different fit between the strategies would be necessary inside the firm, in such a way as to make the most efficient use possible of the relationship between the level of uncertainty in demand (often associated with innovation) and the operational efficiency.

Finally, the main limitation of the study relates to the limitations imposed by the nature of the work; in other words, carrying out a literature review with the goal of developing a conceptual paper. However, as this is a first step in developing a theory of the relationship between innovation strategies and supply chain strategies, we believe that this study represents a significant contribution to the literature.

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On the Impact of Undershoots at Order Point in the Fill Rate Estimation in Continuous Review Policies for the Lost Sales Case

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Abstract The fill rate is usually computed by using the *traditional* approach, which calculates it as the complement of the quotient between the expected unfulfilled demand and the expected demand per replenishment cycle. However, when dealing with continuous review the common derivation of the order point, order quantity (s, Q) policy simplify the computation of the expected unfulfilled demand per replenishment cycle by means of neglecting undershoots at order point s. This paper shows, by means of some illustrative examples and using simulation, how neglecting undershoots at s introduces a significant bias on the estimation of the fill rate. The fill rate is systematically overestimated by the *traditional* approach. Practical implication of this performance leads to design policies that are less protected than managers may expect. This paper focuses on the lost sales case and discrete demands.

Keywords Inventory · Fill rate · Order point · Undershoots · Lost sales

1 Introduction

In the continuous review inventory system the status of the inventory is known at any moment which implies that all the transactions are registered and reported in real time. This system is based on two control parameters; the order point, s, and the order quantity, Q. Once the inventory position (i.e. on-hand stock + on-order stock-backorders) drops to the order point (or lower) a replenishment order equal to Q is launched and received L periods later. Figure 1 shows the evolution of on-hand

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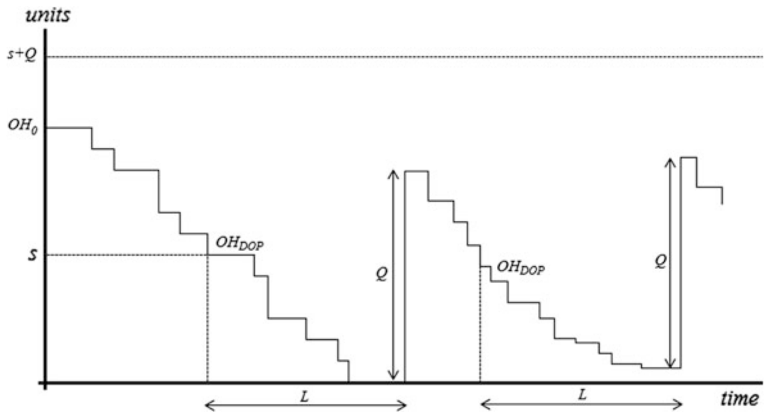

Fig. 1 Evolution of on-hand stock in a (*s*, *Q*) inventory policy

stock in a (*s*, *Q*) inventory policy. Traditionally, it is assumed that the inventory position reaches exactly the order point which implies that all the demand transactions are unit size or that undershoots at the order point are of negligible magnitude compared with the total lead time demand (Silver et al. 1998). However this assumptions seems to be very restrictive in practice and some authors have developed models that explicitly consider the presence of undershoots as shown (Snyder 1984; Vereecke and Verstraeten 1994; Strijbosch et al. 2000) among others. Nevertheless, the probability of having undershoots at the order point has not been introduced in the computation of the most used service measure: the fill rate.

Cardós and Babiloni (2011) deal with the impact of neglecting undershoots in the estimation of the cycle service level. The objective of this paper is to point out the impact of neglecting undershoots in the fill rate (β henceforth) estimation.

The paper is organized as follows. Section 2 presents the notation and assumptions of this paper. Section 3 dedicates to the fill rate definition and points out the mathematical complexity from extending the traditional computation of this measure to the case of considering explicitly undershoots at *s*. Section 4 dedicates to the simulation and the experimental results. In this section also the discussion of the results and the practical implications of neglecting undershoots are pointed out. Finally, conclusions and further research of this work are presented in Sect. 5.

2 Notation and Assumptions

When managing inventories it is required to know how to proceed when an item is out of stock and a customer order arrives. There are two extreme cases: the backordering case (= any unfulfilled demand is backordered and filled as soon as possible); and the lost sales case (= any unfulfilled demand is lost). This paper focuses on the continuous review policy (*s, Q*) for the lost sales case. Although the problem of lost sales was formulated a long time ago by (Karlin and Scarf 1958), inventory research has traditionally focused on systems where excess demand is backordered. This is mainly because characterizing optimal policies when lost sales occur is much harder to formulate than backordering models (Bijvank and Vis 2011; Zipkin 2008). However, the assumption of excess demand being lost is of practical importance in sectors where customers are impatient and they will go to other sources to satisfy their requirements if they do not find what they wish. Hence, having implementable and appropriate expressions to design inventory policies for the lost sales case becomes necessary for practitioners.

This paper assumes: (i) the time is discrete and is organized in a numerable and infinite succession of instants; (ii) demand in an instant is fulfilled with the inventory at the previous time instant; (iii) it is not allowed more than one outstanding replenishment order which implies that $s < Q$; and (iv) the demand process is assumed to be discrete, stationary, with a known demand pattern and *i.i.d.* Note that assumption (iii) is widely used both in the literature and in practice. The common derivation of policies for the lost sales scenario takes this assumption because of the mathematical complexity involved in extending it to more than one replenishment order which is explained in detail by (Hadley and Whitin 1963). In practice, this assumption applies in common situations such as replenishments of a store from a general warehouse in the retail sector where backlog is not allowed. On the other hand, the hypothesis of stationary and *i.i.d.* demand is also a common assumption in inventory research that can be extended for the non-stationary demand scenario when forecast errors of the demand are *i.i.d.*

Notation in Fig. 1 and in the rest of the paper is:

s	order point (units),
Q	size of the replenishment order (units),
L	lead time for the replenishment order (time),
t	elapsed time from the reception of the order launched in the previous cycle (time),
OH_t	on-hand stock at instant t (units),
OH_0	on-hand stock at the beginning of the cycle and at the end of the previous cycle (units),
OH_{DOP}	on-hand stock when the order point is reached and the replenishment order is launched (units),
D_t	demand at instant t (units),
D_L	aggregated demand obtained adding up the demand in L instants (units),
D_{OP}	demand from the beginning of the cycle to the order point,
$f_t(\cdot)$	probability density function of demand in t.

3 Traditional Estimation of the Fill Rate

The fill rate is defined as the fraction of demand that is immediately fulfilled from on-hand stock (Lee and Billington 1992). β is the service measure most popular in practical environments given that it considers not only the possibility that the system is out of stock (van der Heijden 2000), but also the size of the unfulfilled demand when it occurs (Chopra and Meindl 2004; Tempelmeier 2007).

Common approach to estimate it consists of computing the number of units short, i.e. the demand that is not satisfied, instead of computing directly the fulfilled demand per replenishment cycle. This approach, known in the related literature as the *Traditional* approximation and denoted by β_{Trad} further on, consists of calculating the complement of the quotient between the expected unfulfilled demand per replenishment cycle (also known as expected shortage) and the total expected demand per replenishment cycle as follows:

$$\beta_{Trad} = 1 - \frac{\mathrm{E}\left(\text{unfulfilled demand per replenishment cycle}\right)}{E\left(\text{total demand per replenishment cycle}\right)} \tag{3.1}$$

Neglecting undershoots leads to consider that when the inventory position is exactly at s a replenishment order equal to Q is launched. Then, the expected unfulfilled demand is:

$$E\left(\text{unfulfilled demand per replenishment cycle}\right) = \sum_{D_L=s+1}^{\infty} (D_L - s) \cdot f_L(D_L) \tag{3.2}$$

This expression can be found for example in (Chopra and Meindl 2004) for the continuous case. Note that neglecting undershoots leads to simplify the computation of the unfulfilled demand per replenishment cycle, since one of the most difficult parts in the exact computation of the fill rate is to know exactly the on-hand stock (OH_{DOP}) when the order point has been reached (and is below s).

Finally, to compute the expected total demand per replenishment cycle, we compute the expected demand from the beginning of the cycle until the moment that inventory positions reaches the order point plus the total demand during the lead time.

Therefore, β_{Trad} when demand follows any discrete distribution function can be estimated with the following expression:

$$\beta_{Trad} = 1 - \frac{\sum_{D_L=s+1}^{\infty} (D_L - s) \cdot f_L(D_L)}{\sum_{D_{DOP}=0}^{Q} D_{DOP} \cdot f_{DOP}(D_{DOP}) + \sum_{D_L=0}^{\infty} D_L \cdot f_L(D_L)} \tag{3.3}$$

Note that expression (3.3) can be used by any discrete demand distribution.

4 Simulation and Experimental Results

This section illustrates the performance of β_{Trad} against the simulated fill rate, β_{Sim}, which is computed as the average fraction of the fulfilled demand in every replenishment cycle when considering 20,000 consecutive periods:

$$\beta_{Sim} = \frac{1}{T} \sum_{t=1}^{T} \frac{\text{fulfilled demand}_t}{\text{total demand}_t} \tag{4.1}$$

where T indicates the total number of replenishment cycles. This simulation uses the data from Table 1 which encompasses 15 different cases with Pure Poisson demands which fulfill the smooth and intermittent categories according to (Syntetos et al. 2005) categorization framework. Figure 2 presents the comparison between β_{Trad} and β_{Sim} for the Table 1 cases and shows the significant deviation that appears between them.

As expected, β_{Trad} tends to overestimate β_{Sim} for almost all the cases. This fact can be explained if we analyse the real impact of neglecting undershoots at the order point. For example, if the system at t is one unit above the order point and demand of more than 1 unit (for example 2 units) take place at $t + 1$, then the system launches a replenishment order when the inventory position and the on-hand stock is exactly $s-1$. Therefore, the on-hand stock which is available to satisfy the expected demand during L is less than expected. In this case, the real fill rate will be

Table 1 Set of data

Lead time L = 2; 3
Order quantity Q = 5; 7
Order point s = 2; 3
Demand variability (Poisson distributed) λ = 0.1; 0.5; 1; 1.5; 5

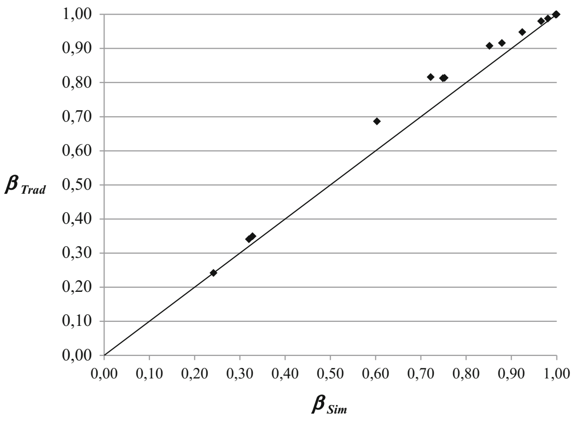

Fig. 2 β_{Trad} versus β_{Sim} for the cases from Table 1

lower that the fill rate computed by means of the *Traditional* approach since the latter is assuming that the on-hand is higher than it really is. This example works to illustrate why neglecting undershoots introduces a significant bias on the estimation of the fill rate. Furthermore, deviations tend to be higher for medium values of the fill rate (between 0.60 and 0.80), as expected.

Practical implications of using the *Traditional* approach in inventory management are found when designing inventories policies to guarantee a target fill rate. In this case, the control parameter of the policy and the safety stock are determined taking into account the service level the manager wants to reach. If for that purpose we use an expression that overestimates the real fill rate, we will obtain a order point and a safety stock which is lower than the required and therefore the system will be less protected against stockouts that the manager would expect. This implication is really important in industries in which the related cost of the stockout is very high.

Table 2 shows deviations which arise from any of the cases we illustrate in this Section. A quick look into the results revels the same results that have been commented above: (i) Deviations are always negative, which means that β_{Trad} overestimates the real fill rate; (ii) the higher deviation (9.44%) appears for medium values of the fill rate (β_{Sim} = 0.7218), and is in this interval (between 0.60 and 0.80) where we find the highest deviations; (iii) maximum deviations appear for smooth demand categories, as expected. When λ < 1 the probability of having demand sizes more than one unit is very small so that the assumption of unitary demand is fulfilled and as a consequence undershoots does not take place.

Table 2 Deviations between β_{Sim} and β_{Trad}

λ	Demand Category	s	Q	L	β_{Sim}	β_{Trad}	Deviation (%)
0.1	Intermittent	2	5	3	0.9980	0.9992	−0.12
0.1	Intermittent	3	7	3	1.000	1.000	0.00
0.1	Intermittent	2	5	2	0.9995	0.9997	−0.03
0.5	Intermittent	2	5	3	0.9240	0.9481	−2.40
0.5	Intermittent	3	7	3	0.9807	0.9874	−0.67
0.5	Intermittent	2	5	2	0.9660	0.9800	−1.40
1	Smooth	2	5	3	0.7486	0.8127	−6.41
1	Smooth	3	7	3	0.8791	0.9159	−3.68
1	Smooth	2	5	2	0.8519	0.9076	−5.60
1.5	Smooth	2	5	3	0.6030	0.6860	−8.30
1.5	Smooth	3	7	3	0.7524	0.8136	−6.13
1.5	Smooth	2	5	2	0.7218	0.8162	−9.44
5	Smooth	2	5	3	0.2416	0.2418	−0.02
5	Smooth	3	7	3	0.3277	0.3492	−2.14
5	Smooth	2	5	2	0.3201	0.3408	−2.06

5 Summary and Conclusions

This paper focuses on the (*s, Q*) continuous review policy for the lost sales case and discrete demands. One of the most common assumptions for this policy consists on neglecting undershoots at order point, *s*, and therefore it is assumed that the replenishment order is launched when the inventory position and the on-hand stock are exactly at *s*. This paper deals with the impact that neglecting undershoots has in the estimation of the fill rate. The *Traditional* approach estimates it as the complement of the quotient between the expected unfulfilled demand per replenishment cycle and the total expected demand per replenishment cycle as is represented in Eq. (3.3) for any discrete demand. In this research firstly we simulate a (*s, Q*) system; secondly we compute the fill rate according to its definition; and thirdly we compare the results from the *Traditional* approach. The main result we obtain is that the *Traditional* approach is biased and tends to overestimate the simulated fill rate as a consequence of neglecting undershoots at *s*. Deviations are higher when the demand rate (represented by a pure Poisson distribution) increases. This performance of the *Traditional* approach is especially relevant if using it to determine the control parameters of the policy since it can lead to set an order point lower that it is required to guarantee a target service level.

This paper has revealed some interesting issues that will be addressed in future research projects: (a) the need of developing an exact method to estimate the fill rate for (*s, Q*) policies, lost sales context and discrete demands; and (b) an in-depth analysis of the performance of the *Traditional* approach on the estimation of fill rate which leads to establish under which conditions it is possible to assume there is not undershoots at the order point.

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The Importance of Measurement Systems in the Search for Suitable Packaging Options

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Abstract Packaging is one element that can promote improvements in sustainable and efficient management of supply chains. The main aim of this paper is twofold: Firstly, to identify the main systems for measuring and selecting packaging alternatives based on literature review. Secondly, to carry out a study in 70 Spanish Toy Manufacturers in order to identify if the adoption of these systems contributes to improve competitiveness and sustainability. The methodology used in this empirical analysis was an electronic questionnaire.

Keywords Packaging · Logistics · Supply chain · Measurement systems

1 Introduction

In global and volatile markets, supply chains should increase efforts to improve competitiveness and sustainability by eliminating activities that do not add value and developing innovations in processes and products. In this sense, authors such as Saghir (2002), Hellstrom and Saghir (2007), Garcia-Arca and Prado-Prado (2008), Azzi et al. (2012) or García-Arca et al. (2014) consider packaging as one of the transversal elements that supports an efficient and sustainable supply chain.

These authors show that companies throughout the supply chain have different needs in relation to packaging design. Besides, these needs are not distributed equally in the different levels of packaging (primary, secondary and tertiary packaging), and require an integrated view of packaging, logistics and product. This need has enabled the development of the concepts "Packaging Logistics" (Saghir 2002) and more recently "Sustainable Packaging Logistics" (García-Arca et al. 2014).

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In order to implement efficiency and sustainability in packaging design from a holistic perspective, it would be necessary to use evaluation or measurement systems that ease the choice among different alternatives. These alternatives are associated to design decisions, such as dimensions, materials (type and quality), structure (relationship among primary, secondary and tertiary packaging) and aesthetic characteristics (shape, colours or text). This need may be justified because not all companies and supply chains are similar and, therefore, they do not have the same type of design requirements and, obviously, the same costs. The need for these evaluation or measurement systems is mentioned in recent literature by authors such as, Saghir (2002), Hellstrom and Saghir (2007), Svanes et al. (2010), Dominic (2010), Azzi et al. (2012) or García-Arca et al. (2014).

Within the previously mentioned context, the main objective of this paper is to validate to what extent implementing measurement systems for comparing packaging design alternatives contributes to improving efficiency and sustainability throughout the supply chain. To do this, firstly the main systems for measuring and selecting packaging alternatives are justified, based on a literature review. The development of these systems is analyzed quantitatively in a sample of companies.

2 A Review of Measurement Systems for Comparing Packaging

A suitable packaging design could be considered as a "silent salesman" to highlight some features of the products that promote the differentiation capacity. Obviously, this commercial approach should help to improve the sales. However, the sales increase is "a posteriori" indicator as it measures the design usefulness once it has been implemented. An improved way of measuring the commercial impact of one packaging design before its implementation ("a priori") is the adoption of comparative tests between competitors' packaging alternatives, also known as "Benchmarking" techniques (Gelici-Zeko et al. 2012; Magnusson et al. 2012). These tests are usually performed at the level of primary packaging.

On the other hand, a suitable packaging selection can decrease global supply chain costs. Therefore, costs analysis is an interesting way of "a priori" assessment of options before implementing a new product and packaging (Morabito et al. 2000; García-Arca and Prado-Prado 2006, 2008; Kye et al. 2013; Wever 2011; García-Arca et al. 2014; Mejía-Argueta et al. 2015). These costs can be both direct, such as purchase of packaging and waste management; and indirect, such as packing, complaints and losses due to poor packaging, handling, warehousing, and transport throughout the supply chain, including the points of sale. This indirect perspective of costs prevent many companies from fully understanding the pros of selecting a good packaging design (García-Arca and Prado-Prado 2008).

However, when trying to measure the suitability of a packaging selection from other perspectives, the evaluation system is less clear. In many cases, it is almost impossible to translate this in economic terms. For instance, introducing a protective requirement in packaging could be partially assessed in economic terms by the cost of losses. However, it would be more difficult to measure the dissatisfaction that these losses generate along the supply chain (including the customer), as this impact does not appear necessarily in sales (at least, immediately).

Similar problem is found when trying to value the environmental costs of different packaging options. Although some of these costs could be partially measured, such as Green Dot or returnable packaging systems (Mollenkopf et al. 2005; Pålsson et al. 2013), other costs are not easily measured.

This is the case of the Life Cycle Assessment (LCA) technique the most commonly used system for measuring environmental impact, in accordance with ISO 14040. This technique measures, basically, the carbon footprint generated by the product, including their components (for example, the packaging). In this sense, authors such as Svanes et al. (2010), Azzi et al. (2012), Grönman et al. (2013) and García-Arca et al. (2014) highlight the need for an integrated analysis of the packaging life cycle and that of the product contained within it. In literature, there are some examples of the application of LCA technique to packaging and products. Among other references, we can mention Singh et al. (2006), Levi et al. (2011), Williams and Wikström (2011), Albrecht et al. (2013), Wever and Voghtländer (2013), Molina-Besch and Palsson (2013), Bertollucci et al. (2014), Accorsi et al. (2014) and Siracusa et al. (2014).

In this context, among the most important initiatives in the field of comparing packaging alternatives from an environmental perspective, we can remark the software COMPASS ("Comparative Packaging Assessment") which is used by companies like Procter & Gamble, Johnson and Johnson or UPS. COMPASS allows the comparison up to four different packaging alternatives from an environmental perspective throughout its supply chain, from manufacturing to the end of its life. Likewise, we can find other tools for comparing packaging alternatives from an environmental perspective. Thus, we can mention a platform in the ECOEMBES web page (www.ecoembes.es), where it is possible to compare different packaging alternatives with the best option in a specific category of product. The name of this tool is "Best in class" (ECOEMBES is one of the Spanish association for managing packaging waste under the European Directive 94/62 and its update 04/12).

Going beyond an economic, commercial and/or environmental perspective, different assessment methods have been developed to deal with the difficulties in objectively evaluating each packaging alternative from a multifunctional point of view focusing on the supply chain as a whole. These methods combine quantitative and qualitative scales, which allow for an element of subjectivity in measurement results (García-Arca and Prado-Prado 2008; Grönman et al. 2013). The most widespread of these methods is "Packaging Scorecard", made popular by companies such as IKEA and Walmart. This method, although based on previous research from the Swedish University of Lund, is developed theoretically by Dominic et al. (2000), Olsmats and Dominic (2003) and Dominic (2010). In order to help to the dissemination of the method "Packaging Scorecard" some software tools have been developed, for example, the platform "Scorecard Modelling" (http://www.scorecardmodeling.com) supported by Walmart (Angeles 2012).

On the other hand, we can identify other techniques and tools that deal specifically with some aspects in the pursuit of the best packaging alternative (or good alternatives). Thus, for example, Lee and Lye (2003) or Faccio et al. (2015) focus their measurement techniques on the process of packing. However, other authors have proposed measurement systems, supported by mathematical optimization, for designing the best box (Dominic et al. 2015; Gamez-Alban et al. 2015; García-Arca et al. 2015) or to optimize the cubic volume (Morabito et al. 2000; Wever 2011).

In this context, there are some software tools for helping the packaging design, searching for improving logistics efficiency within the supply chain using different heuristics or metaheuristics techniques (Palletization software). These tools also could be divided into two categories: tools for improving the cubic efficiency in packaging, pallets and trucks with a single type of product; and tools for improving the cubic efficiency in packaging, pallets and trucks with different types of products.

In the first category, we can mention the following software tools: "Cape Pack" (http://www.paltec.net), "Tops" (http://www.topseng.com), "Quick Pallet Maker" (http://www.packwell.co.uk) and "Cube IQ" (http://www.magiclogic.com). In the second category, we can find the following programs: "Max Load" (http://www.topseng.com) or "Cargo Wiz" (http://www.softtruck.com).

Finally, we comment other software tools ("Space Management Software") devoted to improve both efficiency in handling and differentiation capacity at the shelves of the points of sale. This type of programs pursuits to connect the brand image of the product with the rationalization of the resources used in the shops through the comparison of different planograms, in order to maximize the sales and the benefits. Among other programs, we can cite "Spaceman" (www.nielsen.com) and "Qmax" (http://www.qmaxsl.com).

In summary, after the literature review, we can find 6 types of systems developed for measuring different packaging alternatives: Costs, Benchmarking, LCA, Packaging Scorecard, Palletization Software and, finally, Space Management Software. The impact of these systems will be analyzed empirically in the next section.

3 Testing the Impact of Measurement Systems

With regard to the objectives outlined in the introduction section, we present an empirical analysis of companies in order to validate the extent to which implementing measurement systems in packaging design contributes to better performance. In order to achieve this objective, the authors carried out an exploratory study of the Spanish Toy Manufacturing Sector. The technical methodology of the study was the structured electronic questionnaire. The interviewees were mostly logistics/production managers and the number of companies participating in the study was 70. This number means the 70% of the companies in the "Spanish Toy Manufacturers Association" (AEFJ).

The items in questionnaire were valued according to a level of implementation of six types of systems selected in literature review. To evaluate these items, the companies were asked to analyze the values, from 1 to 5 in terms of the Likert scale (where 1 is "not very implemented" and 5 is "very implemented").

To carry out the analysis in companies, two groups were established based on the best or worst results achieved thanks to the changes, improvements and innovations in their packaging (35 companies in each group). For considering the importance of results, the authors use the assessments reported by companies (according to a Likert scale) in the following aspects: the differentiation capacity, the protection improvement, the reduction in the costs of packaging purchases, internal logistics, external logistics, packing and raw materials/components supplying and, finally, the improvement in the environmental behavior.

The first group (Group 1) included those firms expressing obtain the best results (sum of all the assessments in the previous aspects). The second group (Group 2) included companies with the worst performance. The differences between two groups were significant (p-value: 7.0255E-16). In order to analyze the potential interest of measurement systems implementation, a Mann–Whitney U test was applied.

From a cost point of view, we found significant differences between both groups of companies in the development of these measurement systems, with the exception in the costs of packaging waste management (Table 1). The types of cost highest supported in the measurement systems are the packaging purchases, the internal logistics and the packing process. The worst level of development is associated to the external logistics costs and the packaging waste costs. Anyway, although both groups of companies agree on the highest development of systems for measuring packaging purchases, we find differences in the order of the other types of costs depending on the group of companies.

Table 1 Statistic analysis of impact of measurement systems on performance (based on costs)

Type of system for measuring cost	Value	Group 1 (best)	Group 2 (worst)	Statistic analysis	
Packaging purchases	Mean	4.543	4.000	Z statistic	−2.56263
	Variance	0.491	1.059	**p-value**	**0.010***
Packing	Mean	4.086	3.371	Z statistic	−2.81846
	Variance	0.728	1.123	p-value	**0.00482****
Internal logistics	Mean	4.200	3.171	Z statistic	−4.0493
	Variance	0.518	1.146	p-value	**0.00005****
External logistics	Mean	3.743	2.886	Z statistic	−2.78669
	Variance	1.491	1.339	p-value	**0.005****
Packaging waste	Mean	3.600	3.114	Z statistic	−1.45376
	Variance	1.247	1.692	p-value	0.1460

*$p<0.05$; **$p<0.01$

Table 2 Statistic analysis of impact of measurement systems on performance (no based on costs)

Type of system for measuring (no cost)	% of ignorance	Value	Group 1 (best)	Group 2 (worst)	Statistic analysis	
Packaging scorecard	21.43	Mean	2.385	1.517	Z statistic	−2.659
		Variance	2.326	1.401	**p-value**	**0.0078****
Life cycle assessment (LCA)	14.29	Mean	2.517	1.581	Z statistic	−2.824
		Variance	2.116	0.985	**p-value**	**0.0047****
Benchmarking	14.29	Mean	3.357	2.375	Z statistic	−2.555
		Variance	1.942	2.113	**p-value**	**0.0106***
Packaging design software	14.29	Mean	3.066	2.129	Z statistic	−2.381
		Variance	2.409	2.249	p-value	**0.017***
Space management software	10	Mean	2.531	1.7	Z statistic	−2.250
		Variance	2.450	1.320	p-value	**0.024***

*$p<0.05$; **$p<0.01$

Thus, in the companies with the best results the main type of cost (packaging purchases) is followed by the internal logistics costs and the packing costs, while in the companies with the worst results, the order is just the opposite. This situation is similar in the comparison with the types of costs with the worst level of implementation (external logistics costs and packaging waste costs).

On the other hand, regarding other measurement systems (no based on costs), we also found relevant differences in the analysis of companies in each group (Table 2) that supports the positive effect of development of these measurement systems no based on costs. This analysis shows the lowest overall development of these systems to those based on costs (in both groups of companies; obviously, in the study of the deployment of these systems, only companies that know them have been considered). Thus, it is noteworthy the important level of ignorance regarding these systems that exceeds 10% of companies and reaches 21% in "Packaging Scorecard".

In summary, the analysis of the measurement systems implementation points out that a further development of the measurement systems in packaging design actively contributes to better results in almost all groups considered, as summarized in the previous paragraphs. The exception is the system for measuring and comparing packaging waste costs, where we have not found significant differences.

4 Discussion and Conclusions

A suitable packaging solution demands a holistic perspective in order to adapt to the different design requirements. This statement justifies the need for implementing systems for valuing and comparing different packaging alternatives. As it has showed in the paper, a higher development of these systems contributes to achieve the best results in companies.

Unfortunately, the biggest challenge in deploying a measurement system to compare alternatives is how to objectively weighing up design requirements on the same scale, for example, the costs including in techniques such as LCA or in perceived quality by customers. In practice, this involves combining simultaneously some systems. For this reason, the authors propose an evaluation system based on objective cost measurement, but also subjectively combined with, or adjusted to results from other scales or measurement systems. We think that this approach eases decision-making, supplying good (or very good) alternatives.

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How to Do Road Transport More Sustainable? A Literature Review

P. Domínguez-Caamaño, B. Olmedo, M. Rodríguez-García and J.C Prado-Prado

Abstract This paper presents a structured compilation of best practices for road transport. This study is the result of research on the concepts of "sustainability", "road transport" and "supply chain". It was found that the environmental aspect has a meaningful presence, while social and economic are pushed into the background. This literature review collects and organises sustainable initiatives and practices in order to fill a gap in transport field.

Keywords Sustainability · Road transport · Best practices

1 Introduction

Nowadays Climate Change and Sustainability are in the spotlight more than ever before. Road transport contributes to it by emitting Greenhouse Gases (GHG). The annual growth of emissions has accelerated over the past decade.

Transport emissions increased continuously between 1990 and 2007 and have decreased in the last five years. In 2012, CO2 emissions from transport increased by 14.1% compared to 1990 and accounted for 19.7% of total EU-28 GHG emissions. CO2 emissions from road transportation is the main category accounting for more than 90% of the total emissions from this sector (excluding emissions from international aviation and shipping) (EEA 2014).

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2 Methodology

The aim of this paper is to detect the initiatives and best sustainable practices in road transport through a recent literature review. This research aims to serve as a guideline for practitioners who wish to make their transport processes more sustainable, from the "triple bottom line" approach, i.e., economic, environmental, and social sustainability.

In order to develop this literature review we followed a systematic and reproducible methodology proposed by Seuring and Müller (2008). The final sample consists of 100 articles, delimited by 3 criteria. Regarding to the content, the analysis aimed only at papers in English that include the words "sustainability", "road transport" and "supply chain". The search was also limited to journals, thereby avoiding editorials, articles in press, proceedings, and any other type of publication. Finally, publications within the last ten years were only considered. The database used for articles gathering was SCOPUS (www.scopus.com).

3 Results

As shown in Fig. 1, there is a growing trend in these kinds of publications. For the overall sample, we found almost the same proportion of case Studies, empirical studies and mathematical models; which in total represent more than 75% of the publications.

A papers' classification has been developed according to their main focus: economic, social or environmental.

Results show that the environmental aspect has been the most studied area, and represents almost 50% of the publications. It is followed by the economic one with almost 40%, and the social pillar is left with less than 15%.

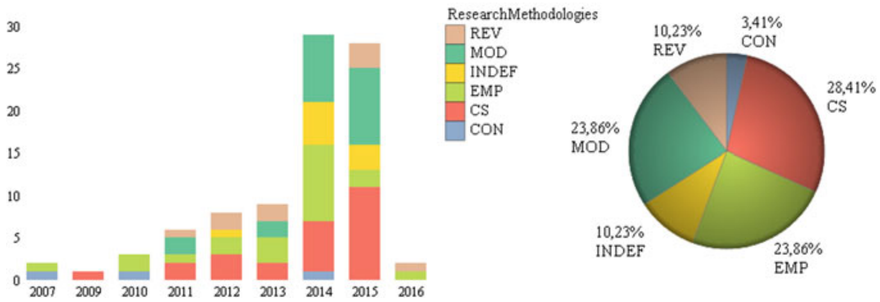

Fig. 1 Publications' distribution according to the research methodology applied

Table 1 Sustainable initiatives and best practices grouped and sorted by number of citations

Issue	Sustainable initiatives/best practices	Nº citations
Closed loop supply chain	Life cycle assessment	14
	Promote backhauling	9
	Recycling	7
Collaboration	Collaboration in SC	12
	Truck sharing	4
	Cooperation with competitors	3
Use of ICT	IT routing and scheduling systems	10
	Use advanced ICT tools: cloud computing, RFID, GPS…	9
Performance management	Performance management	26
	Measuring CO2 footprint	14
	Benchmarking	4
	Global reporting initiative (GRI)	2
Energy efficiency	Intermodality & multimodality	12
	Use of biofuels	10
	Alternative fuel vehicles (AFV)	7
	Eco driving	7
	Improving loading capacity	6
	Alternative modes of transportation	3
	Renew fleet	2
Packaging	Packaging design	10
	Reusable packaging	2

After an individual analysis of the documents studied, we clustered the best practices and initiatives supported by 2 or more articles, according to initiatives explicitly formulated by the authors. The results are shown in Table 1.

3.1 KPI's Management

"If you can't measure it, you can't manage it". The concern about performance measurement has grown recently, starting from financial indicators, through operative performance to an integrated vision of environmental, social and economic pillars. Drivers for measuring this performance change depending on the area of study. Whereas the economic field focuses on profitability, social and environmental areas are especially sensitive to legal pressure and image (Zailani et al. 2011). Paradoxically, several studies have proved that social and environmental initiatives might have positive effects on profitability (Colicchia et al. 2013; Carter and Rogers 2008).

Regarding the transportation field, there is a wide literature on what and how to measure performance. There are both literature reviews (Domínguez-Caamaño et al. 2016) and empirical studies (Piotrowicz and Cuthbertson 2015).

The volume of publications is much higher on the environmental dimension, and most of them represent methodological studies, focused on measurement (van Loon et al. 2015). CO2 emissions measurement is the most highlighted environmental indicator (Pieters et al. 2012) through either carbon footprint method (ISO14064:2006) or other standardised methodologies (Farmery et al. 2015).

There is relatively little research on performance measurement from the "triple-bottom line" perspective. Neumüller et al. (2015), showed the importance of inte-grating these three parameters and the risks of ignoring any of them.

3.2 Closed-Loop Supply Chain

The Life Cycle Assessment (LCA) is one of the most developed measurement techniques. Research on this topic has focused on understanding and minimizing manufactured and consumed products' environmental impact. The calculation methodology is explained in detail in ISO14040/44:2006, which evaluates all the life cycle. It takes into account: energy and raw material consumption, emissions, spills and everything susceptible to causing environmental impact (Abbasi and Nilsson 2012).

Reverse logistics has been gaining importance in recent years (Colicchia et al. 2013), since a proper management of reverse flows could result in a decrease of recycling costs, an increase of the average fill rate of trucks and an emissions reduction. All this together contributes to environmental impact reduction (Bing et al. 2013, 2014).

Recycling, reusing and refurbishing are different ways to avoid raw material consumption, while minimizing the emissions and manufacturing associated costs (Bing et al. 2014).

3.3 Packaging

Packaging management plays a significant role in transport efficiency, since its design directly affects truck's available volume (Dang and Chu 2015). Furthermore, packages are the major source of emissions and waste generated by the sector (van Loon et al. 2015).

Searching for more sustainable packaging has been approached from multiple points of view. Streamlining volumes saves packaging materials and increases the amount of product per cargo unit (García-Arca et al. 2014). Recyclable material can be used to improve environmental indicators (Bing et al. 2014), likewise Colicchia et al. (2013) stated that using reusable packaging leads to an even further reduction of impact throughout its life cycle.

3.4 Collaboration

Collaboration in Supply Chain eases resource use optimization. Plenty of successful case studies of collaboration with suppliers, customers and even competitors can be found in our sample (Wang et al. 2015; Danloup et al. 2015; Colicchia et al. 2013; Pieters et al. 2012).

Truck and facility sharing, joint purchasing management or joint technological developments are among the opportunities for cooperation. Several studies proved the advantages in terms of costs, emissions and waste minimization (Danloup et al. 2015).

In spite of collaboration's great potential, there are still many barriers preventing companies from its adoption. The most notable ones are the fear of sharing commercially sensitive information, the asymmetry of cost and benefit allocation, the compatibility of equipment and a lack of common performance measures to monitor the whole process (Mckinnon and Hr 2007; Wang et al. 2015).

3.5 Information and Communication Technology (ICT)

New trends in ICTs support decision-making and improve the flow of communication needed for collaboration.

Route planning algorithm and Vehicle Routing Problem (VRP) are recurring topics in transport literature. This phenomenon is explained because minimised kilometres means simultaneously minimising costs, minimising emissions and improving social wellbeing (less congestion, shorter driver's working time, etc.). Despite the existing literature regarding VRP, nowadays it is still hard to find cases of real implementation of these algorithms. One of the reasons for this is that the assumptions made in the models are unrealistic in a business context. Sanchez-Rodrigues et al. (2010) identified the different causes and sources of supply chain uncertainty which complicate its modelling (schedule constraints, demand volatility, lack of communication, etc.). Software solutions, which are adaptable to particular constraints, such as Logisplan, Optrak or Microsoft MapPoint, are put on the market (Suzuki and Kabir 2015). Truck Appointment System, GPS tracking and RFID are some options options for ICT.

3.6 Energetically Efficient Transport

Reducing energy consumption per cargo unit is one of the main objectives for improving transport sustainability. Accordingly, non-fossil fuel use, such as biofuels, has increased (Liew et al. 2014). Moreover, Alternative Fuel Vehicles (AFV) are being developed. AFVs are characterised by using combustibles such as

Compressed Natural Gas (CNG), ethanol (E85), liquefied petroleum gas (LPG), methanol (M85) or even electricity (Pieters et al. 2012). Nevertheless, biofuels are still miles away from fossil fuels regarding penetration rate (Liew et al. 2014).

Intermodality is another attractive option for increasing energy efficiency, since rail and maritime transport are more energy efficient than trucking (Iannone 2012). Unfortunately, according to literature, European railway development still remains a challenge (Zitz and Matopoulos 2014).

From another viewpoint, fleet renewal could be another solution. Namely, to purchase trucks equipped with the latest technology designed to reduce emissions and fuel consumption (Kudla and Klaas-Wissing 2012). Truck size is a critical parameter to consider when purchasing: the larger (remaining fill rate high), the better (in environmental and economic terms) (Pieters et al. 2012). Proper maintenance also helps energy efficiency levels to remain throughout the service life of the vehicle (Pieters et al. 2012).

Regarding human factor, eco-driving's meaningful potential should not be overlooked (Kudla and Klaas-Wissing 2012). According to European guideline 2003/59/EG, by just applying these simple rules: low revolutions, constant speed and proper vehicle's maintenance, the reduction of fuel consumption is up to 10%.

4 Discussion and Conclusions

Through this literature review, the most studied initiatives to improve sustainability has been compiled and exposed. This study aims to be a link between the academic world and the industry, helping practitioners to improve their transport performance from a "triple bottom line" approach.

Meaningful differences in the level of development of different analysed practices were also identified.

On the one hand, collaborative initiatives, performance management, reverse logistics and packaging have been extensively studied and have a solid background. In addition, there are many experiences of successful implementations as case studies or action research, and empirical studies show that companies do attach importance to these aspects.

On the other hand, there are other practices that do not have enough cases of deployments in real circumstances, despite having enough presence in the literature analysed, such as software programming routes and alternative fuel use vehicles. Future research could focus on conducting case studies or action research where some of these initiatives are implemented, detailing the results and difficulties encountered. This could encourage practitioners to implement these initiatives to enhance sustainability.

In the analysed literature, there are a series of demands and proposals aimed at the policymakers. These proposals include: inter alia, financial support for sustainable initiatives, prices and awards to exemplary companies, tax cuts or policies and environmental requirements standardization (Oberhofer and Dieplinger 2014; Colicchia et al. 2013; Pieters et al. 2012).

Using the proposed practices and initiatives, organizations could improve their long-term profitability while actively contribute to improve people's welfare and preserve our planet.

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Total Cost of Ownership in the Context of Supply Chain Management: An Instructional Case

Paulo Sérgio Lima Pereira Afonso

Abstract This paper presents and discusses an in-class exercise on Total Cost of Ownership (TCO). TCO can be included within the Supply Chain Cost Management (SCCM) framework, being essentially a tool that aims to determine the true cost of buying from a specific supplier. Case studies and instructional cases are important from an instructional perspective and they can be also used as experiments to know more about the effectiveness of TCO in a real context. The case presented here represents an original instrument for the understanding and dissemination of TCO. The case design and materials used are explained and discussed. This case has been applied in the format of short course but it can also be used in class in a program of several weeks. The results obtained demonstrate that this in-class exercise can be used to involve students or practitioners in a dynamic process of learning and discussion on supplier cost management thus, offering several opportunities for experimental research.

Keywords Total cost of ownership (TCO) · Supply chain cost management · Suppliers management · Case study · Instructional case · Experimental research

1 Introduction

The costs with materials and components is one of the most important for most companies and they represent a significant portion of production costs. In many industries, the costs that reflect the purchasing function represent between 50 and 90% of the production cost. Furthermore, the selection of a supplier should not be made taking, as the unique criterion of reference, the price of the goods purchased.

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Companies understood that they should select the best supplier, and the best supplier may not necessarily be the one that sells at the lowest price. There are other significant costs beyond the price of the material or component such as: transportation costs, costs of non-quality and non-compliance, delivery delays, costs in the after-sales service, etc. The literature also addressed various monetary and non-monetary criteria, such as risk, quality, and reliability of deliveries, performance track record and the financial position of supplier. Thus, the selection of suppliers should include, in addition to prices, a wide range of quantitative and qualitative parameters. In fact, the exaggerated focus on acquisition costs that prevailed for many years resulted in many hidden costs or future costs which have been affecting corporate profits without a clear understanding of such situation.

Purchasing plays an important role in the competitiveness of companies and, therefore, there are several methods for the selection of suppliers, based on different selection criteria. Among the existing methods, they may be highlighted the Total Cost of Ownership (TCO), the Life-Cycle Costing (LCC), the Zero-Based Pricing and the Cost-Based Supplier Performance Evaluation. The life-cycle costing considers the purchase price and the costs the organization incurs to use, operate and maintain, and finally the disposal costs of a particular asset, that is, has a focus on the costs that occur after the moment of purchasing. The zero-based pricing and the cost-based supplier performance evaluation are two methods that consider the total costs of suppliers. These methods give special attention to the cost of "doing business" with a particular supplier, i.e. costs prior to purchasing.

The Total Cost of Ownership (TCO) is a methodology used to determine the true cost of buying a particular good or service from a specific supplier, accounting for that all the costs associated using a monetary valuation of all relevant financial and non-financial attributes, for example quality considerations (Ellram 1995). According to Ferrin and Plank (2002), the Total Cost of Ownership (TCO) is a methodology used in leading companies in worldwide supply chains aiming to determine the true cost of buying a particular good or service from a particular supplier, accounting for it all costs associated with the purchasing activity (Degraeve et al. 2005), using the monetary quantification of all financial and non-financial attributes (Morssinkhof et al. 2011). According to Dickson (1966), the main criteria to be considered in selecting a supplier are: quality, delivery, performance history, warranties and claims policies, supplier facilities and production capacity, price, technical capability, financial position, performance procedures, communication systems, reputation and position in the industry, degree of commitment to the business, management and organizational capacity, level of operational control, capabilities in terms of repairing services, location, level of training and existence of reciprocal agreements.

The exercise presented here represents an original instrument for the teaching, understanding and dissemination of TCO practices. It can be used to involve students or practitioners in a dynamic process where participants should understand and apply this cost management technique. The instrument presented in this article intends to complements previous published research and case studies on TCO. It is an exercise that has embedded a series of important concepts which go beyond the current or common understating of TCO.

One class of students has been used to test this instructional case. Thirty five students have participated in this exercise. This article presents and discusses this instructional case. Furthermore, some managerial implications and opportunities for improvements are discussed. In fact, this research work offers a basis for further replications in a classroom setting and it can be also used to demonstrate the features of TCO to an audience of students or practitioners. Furthermore, it can be also used to prepare experiments for a deep analysis and discussion of TCO from different perspectives (Campbell and Stanley 1963).

2 Methodology

The traditional lecture method is still extensively used in classrooms primarily because it is cost-effective, useful for passing on large amounts of information quickly, and presents a minimum threat to students in the sense that they do not need to participate in the process (Beegle and Coffee 1991). Nevertheless, research in higher education (Silberman 1996) and business education (Salemi 2002) shows that effective instructors select strategies that involve students as active participants in the learning process and use a variety of teaching methods and presentation skills to stimulate interest in the subject matter. Further research supports the theory that students learn in a variety of ways; that is, students have varying learning styles and a significant number have learning styles best suited with pedagogical techniques other than lecturing (O'Connor 1999).

This exercise was design to be used as an instrument to explain TCO. It simulates the application of TCO using a real case. All the steps and considerations about TCO are explained in a dynamic process where the participants participate in an iterative process guided by the teacher or by who is responsible for the implementation of the case. The exercise can be a team-based exercise or it can be solved individually. Previous knowledge on TCO and active learning exercises and games is not a requirement or condition but it is important.

In the exercise it is required the computation of TCO using a spreadsheet model and participants are asked to make decisions considering simulated TCO outputs. The exercise begins just after the definition of the main concepts related with TCO, Supply Chain Cost Management, Suppliers Selection and Management and the Fundamentals of Cost Accounting and Management. The conditions for the computation of TCO are explained through an example which is used to guide participants in the use of the TCO model built in spreadsheets. Each student or team receives a kit including several documents and the spreadsheet model. A set of questions and a guide for the teacher has been also produced. The questions can be grouped and presented into different "output-sheets" which can be given successively.

3 Application of the Instructional Case

The instructional case that has been developed follows a well-defined set of steps and a process which can be managed by the teacher. Figure 1 shows these steps indicating the objectives of each of them, the time set for the different tasks, the inputs or material of each phase and the outputs which are expected to be generated. These phases follow the typical teaching case study approach (e.g. the Harvard case study method). Teaching case studies are designed to give a deep understanding and virtual contact with real life situations. They support teaching methods in the most of business schools since the pioneer example of Harvard University and have been introduced with success in other areas namely, in industrial engineering schools.

The case study is supported by several materials namely (1) recommended readings, (2) the case study, (3) the TCO model developed in a spreadsheet, and (4) material for the teacher. The suggested readings have a focus on several concise texts that students have to read before each phase. Six different short documents have been produced to support the instructional case. Participants should go through these documents following the rules defined by the exercise.

Firstly, a concise definition of several fundamental concepts such as Supply Chain Management, Supply Chain Cost Management and Supplier Cost Management is provided, which may be used to promote some debate or simply to clarify and define concepts and assumptions. After that, students will be more prepared to make the readings on TCO and to learn about how they can compute the TCO. Fourteen questions have been produced to guide the instructional case in each of the different phases and to turn the case an iterative process where students are able to learn the concepts behind TCO and how they can compute it. At the end of the learning process, participants will be asked to discuss the results of different situations which will be presented to them (e.g. comparing the TCO of national suppliers, comparing national and foreign suppliers, etc.).

The TCO tool presented in the case requires inputs from four different levels: at a global level (i.e. at the company level), at the level of the business unit (does not

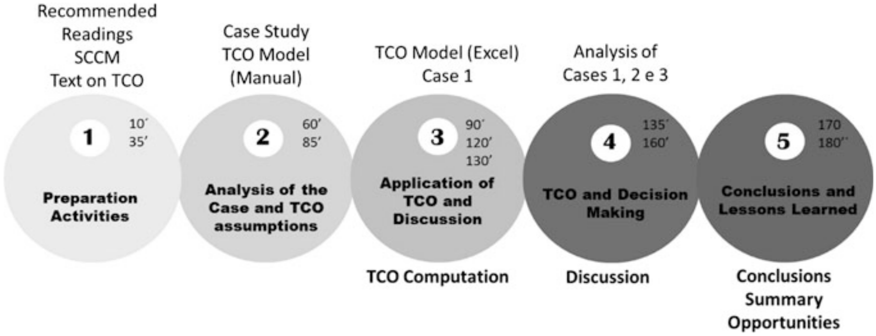

Fig. 1 The five phases of the instructional case

contain figures), at the factory level and finally, at the project level. The first levels are reviewed periodically but they affect equally all projects. The project level is the one that lead to differences in the computation of the TCO. It includes the following data entry fields: project details, supplier information, order costs, shipping costs, inventory costs, supplier's appointment costs, quality costs, other costs.

The company's logistics department developed a document to help the users of the TCO software where we can find typical values for logistics data such as: transportation costs, conditions of shipping, type of stock and inspection procedures.

After the introduction of all inputs, the software produces a detailed TCO for each of the first three years of the project as well as overall results of the TCO for the entire project in the format of tables and graphs. Figure 2 shows the result obtained with the introduction of the data related to Case 1. This case considers a part with a total production volume of 700,000 unities. Three potential suppliers were selected for quotation. All of them are national suppliers. These suppliers have presented a quotation for the supply of this part and it was possible to proceed to calculate the TCO.

Students have used the TCO tool presented in spreadsheets developed for this teaching case study. This model explains the computation of TCO and simulates a TCO software offering a very real experience. This tool is structured in eleven different worksheets: suppliers database, project details, information about the selected suppliers, order costs (e.g. part's price, tooling), shipping costs, inventory costs, nomination costs, quality costs, other costs, output (TCO Table) and output (TCO Graph). The last two worksheets (output) present the results and are automatically produced according to the data entered previously.

Figure 2 represents the TCO of Case 1 on which is visually evident the weight of the different cost components and the cost structure of buying from the three potential suppliers.

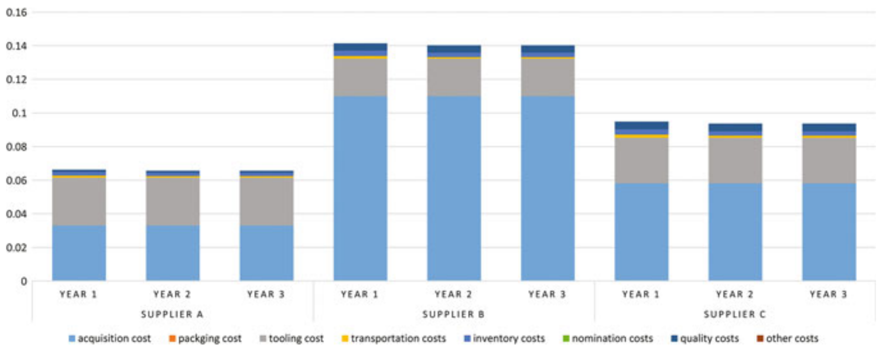

Fig. 2 Detailed TCO

As Fig. 2 shows, the results of the TCO are grouped into 8 classes which permits to have a deep understanding of the influence of the different cost items in the computation of TCO: purchase price, price of packaging, tooling costs, shipping costs, inventory costs, appointment costs, quality costs and other costs.

The TCO tool developed for this instructional case and the different cases allow participants to become familiar with the TCO and offer them the opportunity of using a model similar to a real TCO software. Furthermore, participants are asked to analyze and discuss some aspects related to the implementation of the TCO and to interpret the results obtained in different situations.

4 Discussion

The analysis and discussion is one of the most important aspects of an instructional case. In this case, all the questions used to support the case are important but especially the final questions which request analysis and discussion after the computation of the TCO. For example, in Question 10, participants are asked to comment the fundamental principle of TCO that states that “the cheapest supplier may not be the one with the lowest purchase cost.” In fact, in the cases presented (which represent the most common situations in the company that provided the basis for the design of this case) the lowest TCO coincides with the lower purchase cost. Then, we can question the interest of TCO which is a detailed approach and a very demanding process in terms of cost calculation if this lead to the same results that would be easily obtained only by comparing the price of the parts.

Indeed, the TCO is not only important to select the supplier that represents the lowest cost to the company. TCO is also important to know more and understand the costs associated with suppliers in order to give to the buyer a better bargaining position and support a more effective managing of supplier’s related costs. In fact, as it can be seen also from Question 12, despite that purchasing cost represents a significant portion of the total computed cost, the calculation of TCO is important to show the real dimension of the cost of buying from a particular supplier. In the cases that have been studied, the TCO (total cost) is between 1.5 and more than 3 times the purchase cost. Therefore, other costs beyond the purchase cost are (very) important and must be managed properly.

In Case 2, three national suppliers are compared with an Asian supplier. The supplier with lower TCO is simultaneously the one with the lower price per unity. However, it is clear that the global cost goes far beyond the acquisition price. Indeed, the total costs of providing this part is equivalent to a value between 2 and 3 times the acquisition costs. The cost of the part is the most significant cost item but in all the cases, such costs are less than 50% of total cost. With an accurate perspective of the TCO, the company can track and find more cost-reduction opportunities. Table 1 shows these cases.

Another important aspect is that the TCO permits to detail the components of the total cost, and such information can be used to negotiate cost reductions in new

Table 1 TCO versus acquisition costs

	Supplier A	Supplier B	Supplier C	Supplier D
Acquisition costs (€)	0.4794	0.2419	0.2310	0.2431
TCO (€)	1.1563	0.7434	0.5148	0.5115
TCO/part's price	2.4	3.1	2.2	2.1

rounds of request for quotation. In fact, it was what has happened in Case 2, in which suppliers C and D have presented very similar values in a first round of quotations. The company has selected Supplier C and TCO information highlighted some opportunities for cost reduction and improvements.

TCO has evident advantages and contributes positively for a better management of suppliers' costs. However, it can be complicate to implement because requires very detailed information and some of that information may be subjective (e.g. quality costs), estimated with a high degree of uncertainty or difficult to obtain. In these cases, the TCO can be used to identify the most relevant cost items which can be used to compute a proxy of the TCO based on the most relevant cost items. For example, in the cases presented before, the purchase price and tooling costs represent more than 90% of overall costs, being the inventory the third most significant cost element. The remaining items weigh little in TCO and the decision making could focus on these three main items.

Some final considerations can be made. Firstly, this exercise can be proposed to students with more or less additional or previous teaching material on TCO. This material can be based on several readings or previous lessons. Thus, the exercise can be used to test students' knowledge on these issues or it can be used in an earlier stage. Nevertheless, this exercise was designed and applied considering the first approach. This case requires 360 minute classes but a shorter approach of 240 min can be used. Furthermore, it may be also presented in several weeks in a different number of classes or, alternatively, as a take-home exercise with subsequent discussion in class which may include oral presentations or not. This instructional case may be developed individually or by a team of students or other participants. Each participant or team may be asked to answer to all the questions or different questions may be answered by different teams. On the other hand, the results obtained by each team can be measured and a score could be given. The different teams may also be grouped differentially, e.g. one could be for example a buyer, the others, 1st tier suppliers and even 2nd tier suppliers could be considered. Some of the suppliers (i.e. teams) can be involved earlier or later in the buyer's new product development process, being the TCO an important tool to manage the buyer-supplier relationship in such contexts.

During the exercise it was allowed full access to the teaching material. In this exercise it is not necessary that participants are comfortable with the main concepts and techniques of TCO. However, if students have been exposed to TCO, the classroom exercise could be more effective. The time that has been taken to complete each of the outputs should be controlled and recorded in order to determine both the development and the difficult level of each output purposed.

5 Conclusions

This article presents an instructional case and discusses it. It offers a basis for further replications in a classroom setting and also can be used to demonstrate the features of TCO in the context of SCCM activities to an audience of practitioners. Academics and professionals concerned with cost management with suppliers, supply chain cost management and TCO will find this exercise useful. This exercise describes the concepts and techniques of TCO in a user-friendly, in-class activity. In fact, engaging students in such kind of exercises help them to understand and appreciate the concepts involved. Students expressed their appreciation about the exercise and commented that it motivated them throughout the learning process. Two lines of further work can be expected. Firstly, this exercise can be replicated to different audiences of students or practitioners. Secondly, the exercise itself and the methodology may be improved and extended.

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Tourist Route Planning with a Metaheuristic Approach

Çağla Cergibozan and A. Serdar Tasan

Abstract Tourist route planning is encountered in decisions regarding touristic activities. All destination points in the related problem are desired to be visited, but cost is an important factor while making a travel route. The problem is known as the orienteering problem, and several solution procedures are studied in the related literature. In this paper, genetic algorithm is applied as a solution method for the problem, and a case study about tourist route planning is implemented. Results showed that popularity of the touristic destinations have a clear effect on selection of the touristic points to be visited in the route.

Keywords Tourist route planning · Orienteering problem · Genetic algorithm

1 Introduction

In travel organizations, selection of the right places to be visited is an important issue because of the limited resources. These resources can be claimed as money, time, energy etc. Beside the attractiveness of the touristic destinations, these limited resources restrict tour organizers to plan a complete route of the places that participants would like to visit. During a touristic visit in a foreign country, travel route should be well constituted so as to maximize satisfaction level of the participants in the tour.

This problem is known as the orienteering problem (OP) (Vansteenwegen et al. 2011; Gavalas et al. 2015), or the selective travelling salesman problem (Laporte and Martello 1990). In the problem, there are a number of places and related scores. A tour is constructed so as to maximize total score by also visiting starting and

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ending points within a fixed time. The problem is frequently encountered in real life examples and has many application areas such as manufacturing, logistics, service systems etc. Genetic algorithm (GA) is a metaheuristic approach which belongs to the class of evolutionary algorithms. The aim of this study is to develop an efficient algorithm to solve OP. In this study, a GA is developed and a local search is implemented to improve the solution. Proposed algorithm is applied to a case study which is based on finding a route for a number of museums and archaeological sites in the Aegean Region of Turkey.

The rest of the paper is organized as follows. In Sect. 2, the problem is defined and mathematical formulation of the problem is given. Literature on solution methods is also investigated in this section. In Sect. 3, developed algorithm is described in detail. In Sect. 4, implementation of the case study is given, and finally in Sect. 5, the study is concluded with the results and discussion on future research directions.

2 Tourist Routing Problem

Assume that $V = \{1, \ldots, n\}$ is the vertex set in which vertex 1 is the first point and vertex n is the last point, and $A = \{(i,j)|i,j \in V, i \neq j\}$ is the arc set. t_{ij} is the travel time between vertex i and vertex j, and S_i is defined as the score of the vertex i. x_{ij} is a binary decision variable equal to 1 if arc (i,j) is included in the tour, 0 otherwise. u_i is the position of vertex i in the route. T_{max} is the allowed time for the route. The objective function of the problem is to maximize the total score.

Mathematical formulation of the problem can be given as follows with refer to Vansteenwegen et al. (2011).

$$Max \sum_{i=2}^{n-1} \sum_{j=2}^{n} S_i x_{ij}$$

$$\sum_{j=2}^{n} x_{1j} = \sum_{i=1}^{n-1} x_{in} = 1 \tag{2.1}$$

$$\sum_{i=1}^{n-1} x_{ik} = \sum_{j=2}^{n} x_{kj} \leq 1 \quad k = 2, \ldots, n-1 \tag{2.2}$$

$$\sum_{i=1}^{n-1} \sum_{j=2}^{n} t_{ij} x_{ij} \leq T_{\max} \tag{2.3}$$

$$2 \leq u_i \leq n \quad i = 2, \ldots, n \tag{2.4}$$

$$u_i - u_j + 1 \leq (n-1)\left(1 - x_{ij}\right) \quad i,j = 2,\ldots,n \tag{2.5}$$

$$x_{ij} \in \{0,1\}; \quad i,j = 1,\ldots,n \tag{2.6}$$

In this formulation, the objective function is maximization of the total score. Constraint (2.1) ensure that the tour is starts with vertex 1 and ends with vertex n. Constraint (2.2) ensure that each vertex is visited at most once. Constraint (2.3) is the time constraint, and constraints (2.4) and (2.5) are sub tour elimination constraints.

Several exact and heuristic methods are studied in the OP literature, and some of them are mentioned here. Golden et al. (1987) examined the OP with a heuristic which consists of route construction, improvement and centre-of-gravity steps. Laporte and Martello (1990) gave integer linear programming formulations (ILP) and some enumerative algorithms for the problem, and stated that the problem is NP-hard. Tasgetiren (2001) studied the OP in which a penalty function is considered, and proposed a genetic algorithm. In the recent articles, Verbeeck et al. (2014) developed an ant colony system based algorithm for the time dependent case of the problem. Archetti et al. (2015) proposed a matheuristic solution approach based on ILP models and heuristics for the team orienteering arc routing problem. Since the problem is NP-hard, a fast and effective solution approach will ensure time and cost savings. Correspondingly a genetic algorithm is developed to solve the problem, and detailed information about the algorithm is given in the following section.

3 Proposed Algorithm

Genetic algorithms are evolution based metaheuristic solution techniques for optimization problems (Gen and Cheng 1997). In a genetic algorithm (GA), a population that consists of individuals is monitored along iterations, and an optimal solution is tried to be reached. During the iterations, some of the individuals in the population are selected for the crossover process and a mutation operation is implemented.

In Algorithm 1, a general procedure for the GAs is given. In the proposed algorithm, steps are as follows. First of all, solution is represented as in Fig. 1. The algorithm is initialized with a random generated population. Fitness values of candidate solutions are calculated considering the features of a maximization problem. After roulette wheel selection procedure order crossover is implemented as the crossover operation. Two exchange is used as a mutation operator, and 2-opt

1	4	2	7	5	10	3	9	8	6

Fig. 1 Chromosome representation (the example route starts with vertex 1 and ends with vertex 6)

Table 1 Parameter values in proposed GA

Parameter	Value
Population size *(p)*	150
Crossover rate	0.8
Number of GA iterations	1000
Mutation rate	0.1
Number of two exchange iterations	10
2-opt rate	0.5
Number of 2-opt iterations	2000

local search heuristic is improved the solution. Best parameter combination is determined by computational experiments. Table 1 displays parameter values that are used in the algorithm.

Algorithm 1: Genetic Algorithm

Input: Initial population
Output: Best solution in the population
Calculate fitness values of candidate solutions
for $t = 1$: *ga_iteration_no*
  Select parents via *selection operator*
  Recombine parents with the *crossover operator*
  Mutate child with the *mutation operator*
  Evaluate solution of the child
  Implement *replacement operation*
end for

4 Case Study

The case study is implemented to a touristic tour including a number of museums and archaeological sites in the Aegean Region of Turkey. Figure 2 displays the destinations to be visited in the map. Table 2 shows the destination points in the case, and corresponding number of visits during year 2015 with refer to DOSIM Müze (n.d.). Archaeological sites are abbreviated as A.S. in Table 2.

These museums and archaeological sites that will be visited are primarily determined according to their popularity. After the identification of the destinations, a score for each point is given. At this point, it is thought that the scores would be in direct proportion to the number of visits. Consequently, normalized score for each point is designated as in Table 2. It is assumed that the tour starts at İzmir Archaeology Museum; and the maximum kilometers that will be travelled is 800. Latitudes and longitudes of the points are derived from Müze (n.d.), Google Maps (n.d.) and Google Earth software. A symmetric distance matrix of the locations is

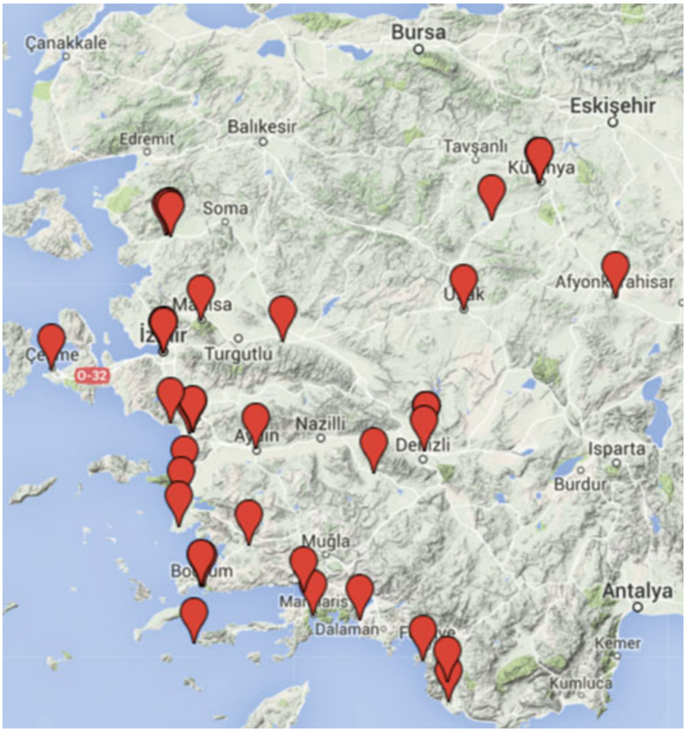

Fig. 2 Touristic destinations to be visited in the map

Table 2 Touristic destinations and their number of visits

Destination	No of visits	Score	Destination	No of visits	Score
İzmir Archaeology Museum	34,185	0.60	Claros A.S.	5,391	0.09
Aydın Afrodisias A.S.	142,017	2.49	Kütahya Museum	18,865	0.33
Priene A.S.	38,436	0.67	Aizonai A.S.	15,172	0.27
Milet A.S.	53,921	0.94	Çini Museum	10,938	0.19
Didim A.S.	76,628	1.34	Uşak Archaeology Museum	10,238	0.18
Aydın Museum	17,429	0.31	*Sardes Gymnasium and Artemis A.S.*	67,404	1.18
Pamukkale (Hierapolis) A.S.	1,731,271	30.30	*Bodrum Underwater Archaeology Museum*	207,610	3.64
Hierapolis Archaeology Museum	120,817	2.12	*Zeki Müren Art Museum*	33,781	0.59
Efes A.S.	1,702,865	29.80	*Kaunos A.S.*	47,765	0.84
Bergama Akropol	188,777	3.31	Letoon A.S.	15,807	0.28
Bergama Asklepion A.S.	110,187	1.93	Kayaköy A.S.	65,816	1.15
Çeşme Museum	52,295	0.92	*Marmaris Castle and Archaeology Museum*	51,691	0.91

(continued)

Table 2 (continued)

Destination	No of visits	Score	Destination	No of visits	Score
Bergama Museum	25,287	0.44	Beçin Castle and A.S.	5,627	0.10
Efes Museum	106,296	1.86	*Halikarnas Mausoleion*	35,843	0.63
St. Jean Church	264,746	4.64	Knidos A.S.	41,936	0.73
Agora A.S.	60,583	1.06	Tlos A.S.	43,980	0.77
Bergama Kızılavlu (Basilica) A.S.	23,590	0.41	*Sedir Island*	151,056	2.65
History Art Museum	22,876	0.40	*Laodikeia*	62,424	1.09
Afyon Museum	6,029	0.11	*Bodrum Ancient Theatre*	39,807	0.70

computed by use of Mapping Toolbox of the MATLAB software. The algorithm is also coded in MATLAB; and performed in a computer with Intel® Core™ i7-3632QM (2.20 GHz and 8.0 GB RAM) processor.

5 Results and Conclusion

Figure 3 shows the resulting tour for the case study. Points correspond to their positions on the map. Resulting tour includes 26 points from the destinations, and it has a total score of 94.7. According to the computational study, the algorithm gives

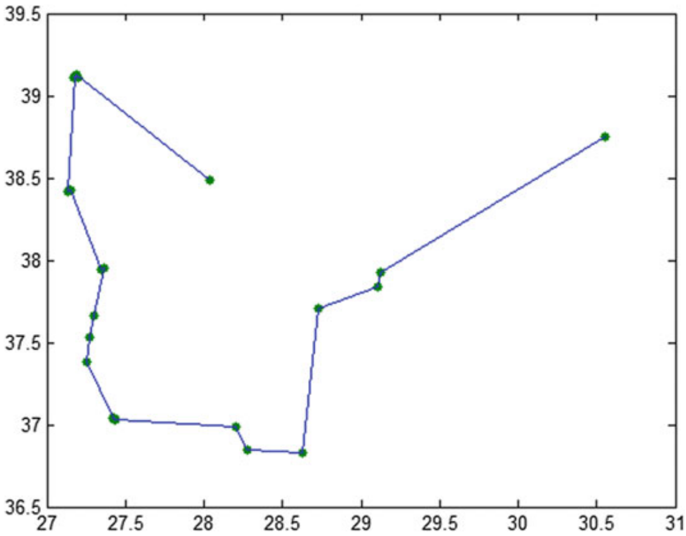

Fig. 3 Resulting route of the proposed algorithm

the result in 30 s with these parameter settings. Resulting tour includes the points written with italic font in Table 2.

In this study, a genetic algorithm is proposed for the tourist routing problem, and a case study is implemented. According to the result of the study, the algorithm is found as fast and efficient, and it can be simply applied to real life situations similar to this problem. Several time constraints can be considered in further studies and alternative tours such as daily, two day etc. can be obtained.

It is thought that the research on this problem seems to continue increasingly due to the complexity of the problem. Besides exact methods and efficient meta-heuristics, future research is expected to concentrate on mixed solution approaches which combine exact methods with fast heuristic procedures. Real life applications for proposed models are also needed in the related literature.

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A Feasible Nurse Routing Plan for the Elderly: Quality and Spatial Trade-Offs

Norina Szander, Lorenzo Brian Ros-McDonnell and Marija Bogataj

Abstract The aim of this paper is to promote links between researchers and practitioners of planning and operations scheduling in eldercare, where the logistics of nursing and other services at home for seniors should be optimally scheduled. Our goal is to create a feasible routing plan, minimize transportation costs while keeping in mind the seniors' personal preferences. As suggested by researchers in delivery activities, the service level is ensured or further enhanced by fixing appointment times or at least narrowing the time windows, in which the service shall be started. We examined the impact on tour length of introducing fixed appointment times in care delivery for seniors, in order to avoid variability of it due to the uncertainty of traffic. The results confirmed our presupposition that fixed appointment times will make the tour longer and the number of required employees higher, in dependence of the time window. Higher the time window more certainly the appointment will be realised in-time as previously determined. The case study on the real data of a Care Centre for the Elderly in one of the Hungarian municipalities shows that the fixed appointment time policy, which would increase the satisfaction of seniors, would require the employment of one nurse in excess at a given spatial dispersion of seniors under regular care. As we quantified the capacity perspective, a trade-off situation emerged between improving the service quality and reaching more patients' locations.

Keywords Fixed appointment times · Long-term care · Service scheduling · Routing

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1 Introduction

With the growing amount of elderly people in the society (United Nations 2013), there is a need to define options for their servicing and long-term care (LTC). The Member States of the European Union are responsible for social protection and LTC provision. Despite the freedom of setting the level of LTC provision in each country autonomously, it is agreed that three common objectives of the Social Protection Committee and the European Commission (2014) are followed:

1. Providing access to everyone to health and LTC services (including the financial availability).
2. Promoting quality in health and LTC, while adjusting the supply to the demand (needs and preferences) of a changing society.
3. Ensure the sustainability of financing; rational use of resources; appropriate incentives for users and providers; and reasonable coordination between care systems and institutions.

These recommendations were supported by OECD, to define the strategies for affordable living in accessible environments for ageing in cities, which involves three principal requirements (OECD 2015):

1. Affordable housing [understood as a combination of housing expense (housing prices, rents) and transport costs].
2. The availability of in-home care services.
3. Access to employment and public and private services by public transport.

European Union long-term vision for health and care sector, leads to an idea of independent living and ageing at home, but there are not many instruments supporting this goal by stimulating innovation that will enable this shift from institutionalized care to home care (European Commission 2015).

The availability of "in-home" care services, following the EU recommendations and the second element of the OECD strategy, depends highly on the available capacity and resource allocation capabilities of the service provider. Since researchers found evidence that dignity and privacy are important for older people (Black and Dobbs 2015; Magee et al. 2008; Reynolds and Beamish 2003; Kane and de Vries 2016), it is advisable for the service provider to respect this, but to be served according to a certain cost (including the time schedule, care resources, etc.).

2 Problem Description

In this paper authors did study home-care services in order to propose a feasible routing plan procedure, that minimize the transport costs and maximize senior satisfaction; as a case study it was examined how home-care services are delivered to the elderly in Zalaegerszeg (Hungary) using the data of the Care Centre for

Elderly (CCE). The focus is to highlight the challenges of organizing a LTC service while improving its quality for the elderly who wish to stay in their home (or have no other option but to stay put).

Delivering care to people's homes means that the elderly live in their own homes and receive care regularly, as needed and advised based on their health conditions by medical practitioners. This situation shows many features identical to the ordinary distribution (pick-up–drop-off) tasks, such as visiting a given number of addresses, performing the tasks with a certain time request, and satisfying the preferences of the customer to the highest level possible. The research community often addressed the logistics challenges associated to freight and service delivery (parcels, cable television repair, and home grocery) but far fewer studies deal with it in the context of delivering home care (Cheng and Rich 1998; Bertels and Fahle 2006; Bennett 2010), some of them include the aspects of LTC (Akjiratikarl et al. 2007; Nickel et al. 2009; Eveborn et al. 2006) and just a few of them deal with the home care crew scheduling problem (Koeleman et al. 2012; Rest and Hirsch 2015; Rasmussen et al. 2012).

Assessing the capacity constraints and finding a way to expand them is not enough if this goes at the expense of the quality; therefore improvements shall be aspired in both fields. Some researchers suggest that in pick-up/delivery activities the service level is ensured or further enhanced by fixing time windows (Bennett 2010; Ehmke et al. 2015). This is common in service industries such as home health nursing, repair services, and home grocery/fashion/gadget, etc., delivery, but in most of the cases they cannot be assigned a certain time, at best they denote a day or half a day (Bennett 2010). The problem addressed in this paper can be summarized as: creating a feasible routing plan of home care for the elderly, minimizing transportation costs, and maximizing the satisfaction of patients by a fixed appointment time or acceptable enough time windows.

We studied and optimized the routing of 9 nurses, altogether having 56 patients in the long-term home care system. Below we show the calculation of optimal routes for nurses, with and without fixed appointment times, and the impact of fixed appointment times on the duration—therefore the cost—of the care delivered to the senior's home.

3 Methodology

The work developed has been based on the quantitative methods developed by Bennett (2010), which incorporate transportation modelling for tactical and operational home health logistics planning problems. We follow the established methodology as it defines home health nurse routing and scheduling (HHNRS) problems, which are dynamic periodic routing and scheduling problems, but instead of dynamic planning we study the LTC delivery at a given point of time. Since we study LTC, where the nurses have the same patients for years, there is no need of dynamic planning. According to the head of CCE, in Zalaegerszeg the typical case is to have 1–2 new patients or less on a monthly basis due to the restrictions in the Hungarian healthcare system to claim LTC services. Therefore the frequency of scheduling new patients is low. The Travelling Salesman Problem (TSP) is used to define the shortest route of visiting patients. The general form of TSP is well known (1–3), with the subtour elimination constraint (4) based on the Miller–Tucker–Zemlin (MTZ) formulation (Miller et al. 1960), also called sequential formulation (Orman and Williams 2007). Each nurse is assigned to a set of patients, therefore the nurse moves between these patients' homes and CCE. The objective function (1) is to minimize the total distance travelled. Variable x_{ij} equals 1 if the nurse goes immediately from i to j, 0 means otherwise. The nurse has to leave location i after the care tasks are performed, and goes on to only one location j out of the remaining locations, which is taken care of by (2). Equation (3) means that if the nurse is at a particular location at a given moment, the nurse could have come from only one of the locations to the present location. The travel pairwise each location takes a different amount of time (c_{ij}), which is described by the distance matrix ("c" stands for cost, in our case it is the time spent given in minutes, thus care activities and travelling are comparable). The subtour elimination constraint (4) is a vital part of the TSP formulation; it is included to have only one tour, a Hamiltonian circuit, covering all locations for which the nurse is responsible, instead of two or more separate tours adding up to cover all sites. Therefore "dummy" variables u_i are introduced, which represent the sequence in which city i is visited, while values of u_i are arbitrary real numbers.

$$\begin{aligned} &Minimize \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}\, x_{ij} \\ &x_{ij} = 0, 1 \end{aligned} \tag{1}$$

$$\sum_{j=1}^{n} x_{ij} = 1 \forall i \tag{2}$$

$$\sum_{i=1}^{n} x_{ij} = 1\ \forall j \quad i = 1 \ldots n-1 \quad j = 2 \ldots n \tag{3}$$

$$\begin{aligned} &\mathrm{u_i} - u_\mathrm{j} + \mathrm{n}x_{\mathrm{ij}} \le \mathrm{n} - 1 \\ &u_i \ge 0 \\ &x_{ij} = 0, 1 \end{aligned} \tag{4}$$

Several different variants of TSP can be solved with Microsoft Excel, using spreadsheets, instead of solvers designed especially for TSP (Rasmussen 2011). There is a drawback to this, mentioned by Lee and Raffensperger (2006), in that Excel is not the convenient choice for large scale instances and visual display of network graphs. Our case does not operate with a large number of addresses, i.e. only 5–9 addresses per nurse and for demonstration we consider maps being suitable enough. The maximum runtime of the solver was set to 180 s, but in every case it provided the optimal solution before the time limit.

The routes were created based on the list compiled by the CCE, in order to take into consideration the *individual needs of elderly*: most importantly they match the elderly to the nurse with the appropriate education and skills, keeping in mind the personal preferences as well. Some patients and nurses can have a certain history either pleasant or unpleasant—they are equally important—, which is considered as they shall not violate anybody's privacy, therefore we did not change the assignment of nurses. Throughout our calculations all problem data are non-negative integers. The duration, $c(T)$, of the tour adds up from the travel (c_{ij}) and care (w_i)—it starts and ends at the CCE and could be prolonged over 8 h (regular working time) for x minutes by an additional costs a per hour:

$$\begin{aligned} & c(T) = c_{0F} + \sum_{i=1}^{n}\left(\sum_{j=1}^{n} c_{ij}x_{ij} + w_i\right) + \mathrm{c_{L0}}\, c(T) \leq 8 * 60 + x \\ & x \geq 0 \\ & min(c(T) + ax/60) \end{aligned} \tag{5}$$

Reaching the first patient from the CCE is denoted as $\mathrm{c_{0F}}$ and the return trip from the last patient to the CCE is denoted as $\mathrm{c_{L0.}}$ The second case is the tour with time windows (T_δ), where the nurses' shifts are divided into regular intervals (*grid spacing noted as* δ *in the continuation*) to arrange their arrival to their patients at appointed time. That can occur at any quarter of an hour, for example 8:15, 8:30, 8:45, or 9:00, as we set the time windows to be 15 min (δ = *15′*). This gives some flexibility and ensures predictability at the same time. In real life traffic is unpredictable; the same distance may take different times to cover under certain conditions, for example in the morning peak, during holidays, and based on the transport mode selected. The grid spacing is designed to smooth the variability, thus the uncertainty of service delivery. The cost is calculated similarly to the first case, complemented with the presence of the grids which can induce idle time in addition to travel and care when the duration of caring for the i elderly and travelling to the next one cannot be divided by δ without a remainder. The first patient is assigned to the first appointment time, and then the earliest feasible appointment time is assigned to each patient, given the sequence of servicing the seniors. By adjusting Eq. (5) we use Eq. (6):

$$\begin{aligned} & c_\delta(T) = c_{0F} + \sum_{j=1}^{n}\sum_{i=1\mathrm{i}\neq \mathrm{L}}^{n-1}\left\lceil \frac{c_{\mathrm{ij}}x_{ij} + w_i}{\delta}\right\rceil \delta + w_L + c_{L0} \\ & c_\delta(T) \leq 8 * 60 + x \\ & x \geq 0 \\ & min(c_\delta(T) + ax/60) \end{aligned} \tag{6}$$

We assume that the nurses are able to leave the CCE in order to arrive on time to the first patient (c_{0F}), i.e. without inducing any idle time, therefore this is added to the tour similarly to the return trip from the last patient (c_{L0}), separately from the grid spacing. The duration of idle periods ($I_{ij}x_{ij}$) equals to the difference between care and travel rounded up to the length of grids and the actual duration of care and travel. This is described in the Eq. (7):

$$I_{ij}x_{ij} = \begin{cases} \left\lceil \frac{c_{ij}x_{ij} + }{\delta} \right\rceil \cdot \delta - w_i - c_{ij}x_{ij} & \Leftarrow x_{ij} = 1 \\ 0 & \Leftarrow x_{ij} = 0 \end{cases}, \forall i,j \quad (7)$$

4 Results and Discussion

The calculations of time requirements of the tours with and without fixed appointments produced similar results to the findings of Bennett (2010), as was expected. The tour with time windows requires more time altogether than the first case of visiting patients in a sequence, regardless of arrival time. The extent of the difference is quite significant, while arriving at specified points of the day results in unavoidable idle periods. Figure 1 shows the length (in minutes) of travel and care activities with fixed appointments, including the time elapsed when the nurse is idle.

The schedules are extended by idle periods, as it is shown in the Fig. 2. The travel time—therefore its cost—is the same, because nurses follow the same routes, the same distances, while the difference occurs in the working hours of nurses. Regarding each route, the range of excessive time is between 24.3–86.6 min. The idle periods summarized for all 9 nurses is 364.3 min. Keeping in mind the

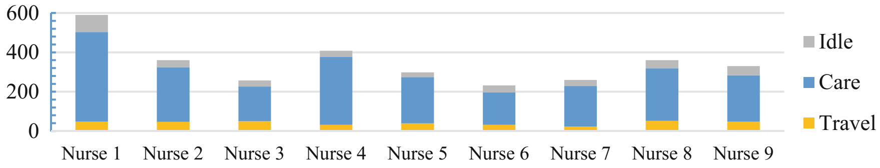

Fig. 1 Time requirement of travel, care, and care with time windows

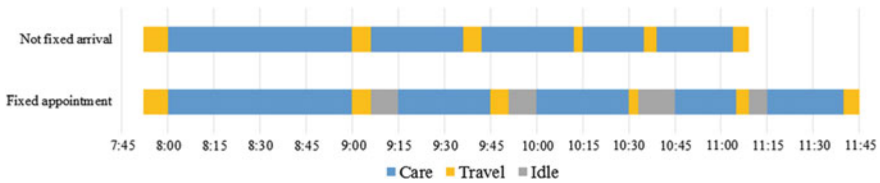

Fig. 2 Sample timeline when the arrival has no time windows, and when appointment times are fixed

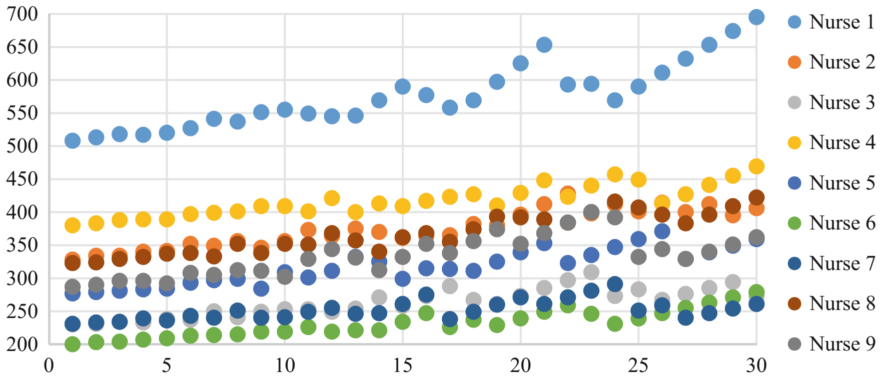

Fig. 3 Total time of tours for each nurse when the length of time windows are different ranging from 1 to 30 min

regulations of working overtime—every hour commenced overtime counts as a full hour—, from a cost point of view, this means each nurse would figuratively work 1 or 2 extra hours, altogether 10 h a day. To highlight the consequence of this extra cost we note that overtime salaries are higher, therefore the expenses are higher than if one more nurse working in regular shifts is employed to reach the service quality improvement provided by fixed appointment times. This cost varies according to the price of labour in different economies. The sensitivity of the result is presented in Fig. 3, where total length of tours is shown with different grid spacing of schedules.

Analysing the value of idle time in working period, the time spent with travelling (≈372 min) and the duration of idle time before the service could be started (≈365 min) is roughly the same. We should carefully consider what is more valuable to LTC providers and clients, nevertheless, excessive resources should be reasonably utilized. They should set up their preferences between being sharply on schedule, so that they can improve service quality, or being able to cover an extended area and deliver health care to the homes of more elderly.

5 Conclusion

The efficient use of resources—including workforce and knowledge—is an important issue in most business strategies. We simulated the routing and schedule of nurses performing LTC services in Zalaegerszeg, Hungary. As suggested by researchers in delivery activities, the service level is ensured or further enhanced by fixing appointment times. The nurses' daily routes were studied both with and without fixed appointment times and the results showed significant additional time requirements. The higher the time window is, the easier for the nurses to arrive on time even with hectic traffic, but it induces more idle time.

With fixed appointment times the extra time requirement of a tour can add up to 365 min in a busy day with a grid of 15 min. These extra approx. 6 h could be used to take care of older people if the money for overtime were spent on hiring one more nurse in CCE. In terms of satisfying the demand, this means 5–9 more patients scheduled daily without fixed appointment times. In our study, the trade-off became quantified from the spatial point of view, i.e. CCE could reach 5–9 more patients daily. For a full comparison, we should know the worth of predictability in visiting the elderly patients.

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Part IV
Production

Minimizing Lost-Work Costs in a Mixed-Model Assembly Line

Joaquín Bautista, Rocío Alfaro-Pozo and Cristina Batalla-García

Abstract Mixed-model assembly lines present two issues due to differences in processing times from product types; these issues are the work overload or unfinished work and the useless time or unproductive time. Within this context, we present, in this paper, a new mathematical model for the mixed-model sequencing problem. This model minimizes the costs by lost production and idle productive time. The model also allows processors carry out their workload with a factor activity greater than the normal, in order to reduce the work overload if it is necessary. Obviously it is also considered to provide economic compensation to workers based on their level of activation. Finally, the model is evaluated by a computational experience linked to a real case from the automotive industry.

Keywords Assembly line · Sequencing · Work overload · Useless time · Costs

1 Introduction

Currently there are many productive systems with Mixed-Model Assembly Lines (MMALs). We find some examples in the automotive industry, or door-lock industry, among others (Bautista et al. 2012; Lin and Chu 2014).

These production systems are characterized by high flexibility, because they are able to assemble different product types. This variety in the product portfolio means that both the consumption of components and the use of resources may differ from

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one type of product to another. The latter can cause, on the one hand, the existence of unbalanced stock levels throughout the working day; and, on the other hand, the non-uniform distribution of the workload throughout the working day at workstations.

For these reasons the Mixed-Model Sequencing Problem (MMSP) is especially important in MMALs; while it is true that almost any sequence of product mix is technically feasible, not all sequences have the same economic impact because the component consumptions and the load distribution will be one or another depending on the sequence (Boysen et al. 2009).

A sequence with a non-uniform distribution of workloads may involve both the appearance of work overload, W, as the occurrence of useless time, U; consecutive sequencing of product units with processing times longer than the time that has the workstation to work on a unit (cycle time, c, measured at normal activity, $\alpha^N = 1.0$) can cause the processor does not finish the required work and thus it generates work overload, even though stations have more time to retain the product unit (i.e., time window $l_k - c \geq 0$); conversely, if processing times are less than the cycle time, the processor will finish operation on the product unit before cycle time completion and therefore it generates useless time.

This paper is addressed to solve the MMSP avoiding simultaneously the work overload and the useless time. To this purpose, it is presented a new mathematical model whose objective is the minimization of the costs generated by unfinished work and time not used by processor to work on any product unit.

In addition, considering that processors are human resources, we can state that their performance varies throughout the workday. Therefore it is possible to consider that processing times are variable in regard with the work pace or activity of operators into the proposed model, such as it is considered in Bautista et al. (2014, 2015a) and Bautista-Valhondo et al. (2017). In this way the completed work, V, will be increased and the unfinished work, W, will be reduced, favoring the original equivalent objectives from the MMSP-W (Yano and Rachamadugu 1991; Scholl et al. 1998). Obviously, the gains obtained by reduction of work overload and useless time will be used to compensate the activation of workers.

Finally, a case study linked with the Nissan's Engine Plant in Barcelona is used to evaluate the proposed mathematical model. Specifically, from a demand plan that corresponds to a workday, the gains in work overload and useless time will be compared with the reference models.

2 The MMSP. Reference Models

The MMSP consists of establishing a bijection between the elements of a T set (that we enumerate $t = 1, T$) of production cycles and the elements of a Ψ set of products. The elements of Ψ can be grouped in exclusive classes that fulfill $\Psi = \bigcup_{i \in I} \psi_i$ and $\psi_i \cap \psi_{i'} = \{\emptyset\}\ \forall (i, i') \in I$, where I is the set of product types (that we enumerate $i = 1, \ldots, |I|$).

This assignment, of products types to production cycles, is subject to some optimization criterion. There are many criteria, such as the minimization of utility work or inefficiency costs (i.e., idle time, concentration of high workloads) (Fattahi and Salehi 2009), among others. Indeed, many researches simultaneously optimize more than one criterion or include additional conditions, such as Bautista et al. (2015b). In that research and others (Bautista et al. 2014, 2015a), the authors have extended the models for the MMSP by considering human factors. Specifically, the authors proposed the $M4\cup3\_\dot{\alpha}I$ model to minimize the work overload by means of processors' activation, according to a set of functions for the work pace and the collective bargaining agreements. This model is an extension from the $M4\cup3$ model without activity factors.

Similar to the $M4\cup3\_\dot{\alpha}I$ model, we consider, variable-processing times in regard with the activity factor; but unlike the reference model, $M4\cup3\_\dot{\alpha}I$, in this paper, the processors' activation does not be prefixed. Now, the activity is only limited by the maximum and minimum allowable values. In this way, each processor works with an activity factor depending on the workload at each moment. Therefore, the useless time is not affected by the demanded activation, and both issues, work overload and useless time, are simultaneously minimized.

3 Minimizing the Unproductive Costs Maximizing Productivity

From the $M4\cup3\_\dot{\alpha}I$ model (Bautista et al. 2015a), we propose a model that minimizes the costs of work overload and useless time. The new model is able to activate processors in order to minimize the work overload but this activation must be between the minimum and maximum values allowable for the activity factor. The free activation will lead to unsynchronized workstations regarding the work pace.

The new parameters and variables used in the new model, which is proposed in this work, are the following:

Parameters	
L_k	Physical time of presence of operators at workstation $k(k=1,\ldots,\lvert K\rvert)$; it is equal to the workday of operators assigned to the workstation $k : L_k = c\cdot T + l_k - c$
$\dot{\alpha}_t^+$	Upper limit of dynamic activity factor associated with the $t(t=1,\ldots,T+\lvert K\rvert-1)$ period of the extended workday. This extended workday includes T manufacturing cycles at the first station (total demand) and $\lvert K\rvert-1$ additional cycles that are needed to complete the required work at the last station. Here it is supposed all stations have the same upper limit $(\forall t : 1\le t\le T+\lvert K\rvert-1)$.
$\dot{\alpha}_t^-$	Lower limit of dynamic activity factor associated with the $t\,(t=1,\ldots,T+\lvert K\rvert-1)$ period of the extended workday. Here it is supposed all stations have the same lower limit $(\forall t : 1\le t\le T+\lvert K\rvert-1)$

(continued)

(continued)

γ_W	Cost per work overload unit. It is associated with the production fall that is measured through the work overload
γ_b	Cost per time unit of a processor
γ_U	Cost per useless or waste time unit. Here it is supposed $\gamma_b = \gamma_U$
Variables	
$\rho_{k,t}$	Processing time (at normal activity) required to each homogeneous processor by the tth product unit at the station k $(k = 1, \ldots, \lvert K \rvert)$
$\hat{v}_{k,t}$	Processing time applied by each processor (at actual activity, $\dot{\alpha}_{k,t}$) on the tth product unit at the station k $(k = 1, \ldots, \lvert K \rvert)$
$\dot{\alpha}_{k,t}$	Dynamic activity factor associated with the t^{th} operation of the product sequence at the station k $(k = 1, \ldots, \lvert K \rvert)$. This factor is calculated from the normal and actual processing times: $\dot{\alpha}_{k,t} = \hat{v}_{k,t}/v_{k,t} \Rightarrow \hat{v}_{k,t} = v_{k,t}(\dot{\alpha}_{k,t})$
U_k	Useless time by each processor at station k $(k = 1, \ldots, \lvert K \rvert)$, measured at normal activity. This time is considered and penalized according the presence time L_k
Γ	Total operating cost: addition of costs by production lost due to overall work overload and the costs of useless time

And the proposed model, named $M2\_\Gamma$, is as follows:

$$Min\,\Gamma = \Gamma_W + \Gamma_U = \gamma_W \sum_{k=1}^{|K|} \left(b_k \sum_{t=1}^{T} w_{k,t} \right) + \gamma_U \sum_{k=1}^{|K|} b_k U_k \tag{1}$$

$$\sum_{t=1}^{T} x_{i,t} = d_i \quad (\forall i = 1, \ldots, |I|) \tag{2}$$

$$\sum_{i=1}^{|I|} x_{i,t} = 1 \quad (\forall t = 1, \ldots, T) \tag{3}$$

$$\rho_{k,t} = \sum_{i=1}^{|I|} p_{i,k} x_{i,t} \quad (\forall k = 1, \ldots, |K|);\ (\forall t = 1, \ldots, T) \tag{4}$$

$$v_{k,t} + w_{k,t} = \rho_{k,t} \quad (\forall k = 1, \ldots, |K|);\ (\forall t = 1, \ldots, T) \tag{5}$$

$$v_{k,t} - \dot{\alpha}^{+}_{t+k-1} \cdot \hat{v}_{k,t} \le 0 \quad (\forall k = 1, \ldots, |K|);\ (\forall t = 1, \ldots, T) \tag{6}$$

$$v_{k,t} - \dot{\alpha}^{-}_{t+k-1} \cdot \hat{v}_{k,t} \ge 0 \quad (\forall k = 1, \ldots, |K|);\ (\forall t = 1, \ldots, T) \tag{7}$$

$$\hat{s}_{k,t} \ge \hat{s}_{k,t-1} + \hat{v}_{k,t-1} - c \quad (\forall k = 1, \ldots, |K|);\ (\forall t = 2, \ldots, T) \tag{8}$$

$$\hat{s}_{k,t} \ge \hat{s}_{k-1,t} + \hat{v}_{k-1,t} - c \quad (\forall k = 2, \ldots, |K|);\ (\forall t = 1, \ldots, T) \tag{9}$$

$$\hat{s}_{k,t} + \hat{v}_{k,t} \le l_k \quad (\forall k = 1, \ldots, |K|);\ (\forall t = 1, \ldots, T) \tag{10}$$

$$U_k + \sum_{t=1}^{T} \hat{v}_{k,t} = L_k \quad (\forall k = 1, \ldots, |K|) \tag{11}$$

$$U_k, \hat{s}_{k,t}, v_{k,t}, \hat{v}_{k,t}, w_{k,t} \geq 0 \quad (\forall k = 1, \ldots, |K|);\ (\forall t = 1, \ldots, T) \tag{12}$$

$$x_{i,t} \in \{0, 1\} \quad (\forall\, i = 1, \ldots, |I|); (\forall\, t = 1, \ldots, T) \tag{13}$$

$$\hat{s}_{1,1} = 0 \tag{14}$$

In the model, the objective function (1) represents the minimization of total costs arising to lost production and useless time. Constraints (2–5) force the demand satisfaction, the assignment of products to only one sequence position, the determination of the required processing time and the work overload. The set (8–10) defines the start instants of operations. The new constraints (6) and (7) are used to reduce the processing times taking into account the maximum and minimum limits for the activity factor. The set (11) determines the useless time. Finally, constraints (12–14) establish the initial conditions of variables.

4 Economic Compensation

Obviously, increasing the activity factor leads to reduced the cost due to the work overload. In addition, the penalization of useless time should be reflected in an increase in the total work completed (V). Because of this, we believe that the excess effort from processors must be compensated.

In line with Bautista and Alfaro-Pozo (2015, 2016), we present two metrics to calculate the economic compensation. These are based on establishing an economic value to the exertion unit (e.g. $\gamma_b = \gamma_U$) and thus, changing effort in monetary units.

1. Economic compensation by extra activity, per station and cycle ($g^1_{k,t}$) and per station throughout the workday (G^1_k).

$$g^1_{k,t} = \left\{ \begin{array}{ll} \gamma_b \cdot b_k\left(\dot{\alpha}_{k,t} - 1\right)c, & \mathit{if}\ t = 1, \ldots, T-1 \\ \gamma_b \cdot b_k\left(\dot{\alpha}_{k,t} - 1\right)l_k, & \mathit{if}\ t = T \end{array} \right\} \quad (\forall k = 1, \ldots, |K|);\ \ (\forall t = 1, \ldots, T) \tag{15}$$

$$G^1_k = \sum_{t=1}^{T} g^1_{k,t} = \gamma_b \cdot b_k\left[(\bar{\alpha}_k - 1)c \cdot T + \left(\dot{\alpha}_{k,T} - 1\right)(l_k - c)\right] \quad (\forall k = 1, \ldots, |K|) \tag{16}$$

where $\bar{\alpha}_k$ is the average of dynamic activity factors at station $k \in K$.

2. Economic compensation by recovered processing time ($\tilde{v}_{k,t} \equiv v_{k,t} - \hat{v}_{k,t}$), per station and cycle ($g^2_{k,t}$) and per station throughout the workday (G^2_k).

$$g_{k,t}^{2} = \gamma_b \cdot b_k \cdot \tilde{v}_{k,t} = \left\{ \gamma_b \cdot b_k \left(1 - 1/\dot{\alpha}_{k,t} \right) v_{k,t} \right\} \quad (\forall k = 1, \ldots, |K|); \ (\forall t = 1, \ldots, T) \tag{17}$$

$$G_k^2 = \sum_{t=1}^{T} g_{k,t}^2 = \gamma_b \cdot b_k \sum_{t=1}^{T} \tilde{v}_{k,t} = \left\{ \gamma_b \cdot b_k \left(V_k - \hat{V}_k \right) \right\} \quad (\forall\, k = 1, \ldots, |K|) \tag{18}$$

where $\hat{V}_k$ is the applied time at workstation $k \in K$.

5 Case Study

From a daily demand plan of the Nissan's Engine Plant in Barcelona (see mix 1 from Bautista et al. (2012)—Table 7), we compare the results given by the $M2\_\Gamma$ model against the results from the reference models, $M4 \cup 3$ and $M4 \cup 3\_\dot{\alpha}I$. The demand plan is made up of a total of $T = 270$ production cycles (i.e., product units) in an assembly line with $|K| = 21$ workstations; each workstation has one processor $(b_k = 1, \forall k \in K)$ that corresponds with two equivalent operators; each processor has a cycle time of $c = 175$s and a time window of $l_k = 195$s; the cost of one second of work overload, $\gamma_W = 2.28$ €/s, is calculated considering the Consolidated Operating Profit of the line (10% over the profit of one engine, i.e., 400€/engine) and the production cicle ($c = 175$s); the cost of a useless second, $\gamma_U = 0.00\widehat{5}$ €/s, is determined by the hourly cost in Spain in automotive sector (i.e.,. 20 €/h).

In order to evaluate the activation effect we run the models considering the following cases: (1) not consider activation ($\alpha^N = 1.0, \forall k; \forall t$), i.e., run the $M4 \cup 3$; (2) consider a linear function that is equivalent to the average value of stepped function (Bautista et al. 2015a), with a maximum activation of 3.33% with respect to the normal activity, $\overline{\alpha^S}$ (i.e., $\dot{\alpha}_{k,t} = 1.03\widehat{3}, \forall k \in K; \forall t: 1 \leq t \leq T + |K| - 1$ for the $M4 \cup 3\_\dot{\alpha}I$ reference model and $\dot{\alpha}_t^+ = 1.03\widehat{3}, \forall t: 1 \leq t \leq T + |K| - 1$ for the $M2\_\Gamma$ model).

Obviously, not all work overload and useless time will be due to the production sequence. Indeed, given both a line configuration and a demand plan there will be an unavoidable work overload, $W_k^{\circ}(\bar{\alpha}_k)$, that will depend on the station and the activity factor but not on the sequence. On the other hand, there will be also an unavoidable useless time, $U_k^{\circ}(\alpha^N)$, in regard with the workstation but not with the sequence. These values cannot be minimized. For this reason, after obtaining the solution of the models, the unavoidable work overload and useless time will be deducted, in order to not impute their effect on the production costs; these values are calculated as follows:

$$W_k^{\circ}(\bar{\alpha}_k) = b_k \cdot max\{0, P_k(\bar{\alpha}_k) - L_k\} \quad (\forall k = 1, \ldots, |K|) \tag{19}$$

$$U_k^{\circ}(\alpha^N) = b_k \cdot (L_k - V_k^{\circ}(\alpha^N)) \quad (\forall k = 1, \ldots, |K|) \tag{20}$$

where $P_k(\bar{\alpha}_k)$ is the work required with an average activity, $\bar{\alpha}_k$, at the station $k \in K$.

$$P_k(\bar{\alpha}_k) = \sum_{i=1}^{|I|} \frac{p_{i,k}}{\bar{\alpha}_k} \cdot d_i \quad (\forall k = 1, \ldots, |K|) \tag{21}$$

$$V_k^{\circ}\left(\alpha^N\right) = P_k\left(\alpha^N\right) - W_k^{\circ}\left(\alpha^N\right) \quad (\forall k = 1, \ldots, |K|) \tag{22}$$

Considering all the set K of workstations, the overall values are the following:

$$W^{\circ}(\bar{\alpha}_k) = \sum_{k=1}^{|K|} W_k^{\circ}(\bar{\alpha}_k); \quad V^{\circ}(\alpha^N) = \sum_{k=1}^{|K|} V_k^{\circ}(\alpha^N); \quad U^{\circ}(\alpha^N) = \sum_{k=1}^{|K|} U_k^{\circ}(\alpha^N) \tag{23}$$

Therefore, the active work overload and useless time that will be penalysed are:

$$\hat{W} = W - W^{\circ}(\bar{\alpha}_k) \tag{24}$$

$$\hat{U} = U - U^{\circ}(\alpha^N) \tag{25}$$

After running the models, $M4 \cup 3\_\dot{\alpha}I$ and $M2\_\Gamma$, by the Gurobi v4.6.1 solver, on a Apple Macintosh iMac computer with an Intel Core i72.93 GHz processor and 8 GB of RAM using MAC OS X 10.6.7, with a CPU time limit of 2 h; and after discounting the unavoidable values of work overload and useless time, we get the as show in results (Table 1).

Only the $M4 \cup 3\_\dot{\alpha}I$ model reaches the optimal solution with a CPU time of 2 s; $M4 \cup 3$ and $M2\_\Gamma(\overline{\alpha^S})$ models reach the CPU limit, with a gap to the best bound found by the solver of 83.38 and 0.14%, respectively. The worst result is given by the model without activation ($M4 \cup 3$) because of the work overload value. The reference model, $M4 \cup 3\_\dot{\alpha}I(\overline{\alpha^S})$, despite finishing all work required by the demand

Table 1 Values for the unavoidable work overload ($W^{\circ}(\bar{\alpha}_k)$) and useless time ($U^{\circ}(\alpha^N)$) (in seconds), values for the active work overload ($\hat{W}$) and useless time ($\hat{U}$), which are calculated from results given by models (in seconds), daily costs of lost work and unproductive time ($\hat{\Gamma}_W$ and $\hat{\Gamma}_U$), total cost of lost work ($\hat{\Gamma}$) and total costs including the possible economic compensations ($\hat{\Gamma} + G^1$ and $\hat{\Gamma} + G^2$)

	$W^{\circ}(\bar{\alpha}_k)$	$U^{\circ}(\alpha^N)$	$\hat{W}$	$\hat{U}$	$\hat{\Gamma}_W$	$\hat{\Gamma}_U$	$\hat{\Gamma}$	$\hat{\Gamma}+G^1$	$\hat{\Gamma}+G^2$
$M4 \cup 3$	50.0	185,300.0	256.0	92.0	585.1	0.5	585.7	585.7	585.7
$M4 \cup 3\_\dot{\alpha}I(\overline{\alpha^S})$	0.0	185,300.0	0.0	24,936.8	0.0	144.4	144.4	328.2	289.1
$M2\_\Gamma(\overline{\alpha^S})$	0.0	185,300.0	0.0	389.4	0.0	2.2	2.2	4.8	4.6

plan, increases the useless time because it requires an activity factor greater than the normal for all processors throughout the workday. However, the new model eliminates the overload by means of processors' activation when it is needed and avoiding the useless time generation. The latter decreases the compensation costs.

6 Conclusions

In this paper we have addressed simultaneously two issues of mixed-model sequences in assembly lines: the work overload elimination and therefore the completion of all work required by the demand plan, and the minimization of the useless time of processors, reducing the time during which operators do not add value. For this, a mathematical model has been formulated. This model minimizes the costs incurred for each second of unfinished work and for every second of work that is not used by the processor. Furthermore, in order to increase line productivity without increasing useless time, the model allows free activation of processors, whenever necessary, within the limits established by labor agreements.

Through a case study, we can see how the proposed model means lower costs because it eliminates the workload, reduces useless time and involves less economic compensation by the excess effort of processors.

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Comparative Models for Minimizing Ergonomic Risk in Assembly Lines

Joaquín Bautista-Valhondo, Cristina Batalla-García and Rocío Alfaro-Pozo

Abstract We present a new mathematical model for the assembly line balancing problem with the objective of maximizing the line comfort to operators. Besides minimizing discrepancies between the ergonomic risks of workstations, balancing is subject to temporal and spatial conditions for the workstations. To evaluate the performance of the proposed model, we compare it with other mathematical model whose objective is minimizing the maximum ergonomic risk of a mixed-model assembly line. To compare the models, a case study linked to Nissan's engine plant in Barcelona (NMISA, Nissan Motor Ibérica—BCN).

Keywords Assembly line · Ergonomic risk · Mathematical model · Linear programming

1 Introduction

Seeing the evolutionary path from the automobile sector, we can observe how the automobile industry has had to adapt the workplace to workers' characteristics, as well as for all tools used by employees.

Various academics are agreed about defining ergonomics as the scientific discipline able to find a correct interaction between man and the different system elements that are related to environmental conditions and the workspace.

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Sometimes the sophistication of equipment and machines may hinder the adaptation of their characteristics to workers' conditions, although their high-tech profile. For this reason, nowadays it is important to examine and evaluate the working conditions of each workplace and then to apply ergonomic principles. In this way, the conditions, to which workers are subjected, will be improved.

Obviously, all ergonomic improvements are relevant to improve the quality, health, safety and comfort conditions of workers. Indeed, a proper workplace design aims to prevent and avoid illnesses related to inadequate working conditions, as well as ensuring more productive work.

Within the automotive industry, the mixed-model assembly lines (MMALs) are a clear example of the importance of a good workplace design. These lines are able to manufacture identical, similar or heterogeneous products and this flexibility involves variations in the consumption of components and use of resources. This, together with some technological and managerial limitations makes necessary to allocate the set of tasks needed to assembly the products, to the set of workstations of the line in the basis of some optimization criterion.

In general terms, this task assignment problem is named Assembly Line Balancing Problem (ALBP) and it has been widely discussed in the scientific literature. Indeed we can find various taxonomies in literature (Battaïa and Dolgui 2013; Becker and Scholl 2006).

Since the first scientific publication about this problem (Salvensson 1955), many researches have extended the Simple Assembly Line Balancing Problem (SALBP) by means of considering additional restricted attributes. For example, Bautista and Pereira (2007) incorporated into the SALBP the linear area of workstations, defining the Time and Space Assembly Line Balancing Problems (TSALBP). On the other hand, Otto and Scholl (2011) incorporated the ergonomic risk of operations into the SALBP family. And in line with both extensions, more recently, Bautista et al. (2013) defined the TSALBP_erg family in the basis of TSALBP and limiting the minimum and maximum ergonomic risk of the line. Additionally, the authors analysed the impact of the maximum risk allowed on the number of stations of the assembly line (Bautista et al. 2015a).

Latter, in a recent research, the same authors have shown how to minimize the maximum ergonomic risk of stations through Mixed Integer Linear Programming (MILP) (Bautista et al. 2015a) and Greedy Randomized Adaptive Search Procedures (GRASP) algorithms (Bautista et al. 2015b).

Following the works by Bautista et al. (2015a) and taking in mind the criteria satisfaction regarding with working conditions and production efficiency, in this paper we present a new alternative to balancing assembly line in order to maximize the comfort of operators. A comfortable assembly line implies a minimum maximum ergonomic risk and a minimum ergonomic risk range between workstations or, in other words, a minimum difference between the worst and the best workstation in regard with their ergonomic risk values.

Therefore with the aim of maximize the line comfort we present in the next section a new mathematical model to minimize the average absolute deviation of the ergonomic risk between workstations. Besides, in order to evaluate the behaviour of the new model we carry out a case study and we compare the results with those obtained with the model proposed by Bautista et al. (2015a), that here we call it MILP-1: min-max-R and whose objective is to minimize the maximum ergonomic risk. Finally, the conclusions of this research are collected.

2 Mathematical Model

On the basis of compatibility and adjustment functions defined by Bautista et al. (2016), a new optimization model is proposed. The model considers the temporal, spatial and ergonomic attributes and its objective is to minimize the discrepancy between real and ideal values for the ergonomic risk of the line. In this case, the ideal value corresponds with the average risk of the line considering a number of workstations.

The parameters and variables of the model, considering only one risk factor, are the following:

Parameters	
J	Set of elemental task $(j = 1, \rightleftharpoons, \lvert J \rvert)$
K	Set of workstations $(k = 1, \rightleftharpoons, \lvert K \rvert)$
Φ	Set of ergonomic risk factors. Here $\lvert \Phi \rvert = 1$
t_j	Processing time of the task j $(j = 1, \rightleftharpoons, \lvert J \rvert)$ at normal activity
a_j	Linear area required by the elemental task j $(j = 1, \rightleftharpoons, \lvert J \rvert)$
χ_j	Category of the task j $(j = 1, \rightleftharpoons, \lvert J \rvert)$ associated with the considered risk factor
R_j	Ergonomic risk of task j $(j = 1, \rightleftharpoons, \lvert J \rvert)$ associated with the considered risk factor. Here, $R_j = t_j \cdot \chi_j$
P_j	Set of direct precedent tasks of the task j $(j = 1, \rightleftharpoons, \lvert J \rvert)$
c	Cycle time. Standard time assigned to each workstation to process its workload (S_k)
m	Number of workstations. In this case, $m = \lvert K \rvert$
A	Available space or linear area assigned to each workstation
R^{med}	Average ergonomic risk of the line and ideal risk of each workstation regarding the considered risk factor and the demand plan. That is: $R^{med} = \frac{1}{\lvert m \rvert} \sum_{j=1}^{\lvert J \rvert} R_j$
Variables	
$x_{j,k}$	Binary variable equal to 1 if the elemental task j $(j = 1, \rightleftharpoons, \lvert J \rvert)$ is assigned to the workstation k $(k = 1, \rightleftharpoons, \lvert K \rvert)$, and to 0 otherwise
S_k	Workload of workstation K. Set of tasks assigned to the workstation $k \in K$: $S_k = \{ j \in J : x_{j,k} = 1 \}$
$R(S_k)$	Ergonomic risk associated with workload S_k

(continued)

(continued)

$\delta_k^+(R)$	Ergonomic risk excess at workstation $k \in K$ with respect to the average value $\delta_k^+(R) = \left[R(S_k) - R^{med}\right]^+$
$\delta_k^-(R)$	Ergonomic risk defect at workstation $k \in K$ in regard with the average value $\delta_k^-(R) = \left[R^{med} - R(S_k)\right]^+$
$\Delta_R(R(\Phi))$	Sum of rectangular deviations of ergonomic risk
$AAD(R(\Phi),\ m)$	Average absolute deviations of ergonomic risk depending of the number of workstations m. $AAD(R(\Phi),\ m) = \frac{1}{m}\Delta_R(R(\Phi))$

And the proposed model, named MILP-2: min_AAD-R (Average absolute deviations of ergonomic risk) is the following:

$$min\ AAD(R(\Phi)) = \frac{1}{m}\ \Delta_R(R(\Phi)) = \frac{1}{m}\sum_{k=1}^{|K|}\left[\delta_k^+(R) + \delta_k^-(R)\right] \tag{1}$$

Subject to:

$$\sum_{k=1}^{|K|} x_{j,k} = 1 \quad \forall j \in J \tag{2}$$

$$\sum_{j=1}^{|J|} t_j \cdot x_{j,k} \le c \quad \forall k \in K \tag{3}$$

$$\sum_{j=1}^{|J|} a_j \cdot x_{j,k} \le A \quad \forall k \in K \tag{4}$$

$$R(S_k) - \sum_{j=1}^{|J|} R_j \cdot x_{j,k} = 0 \quad \forall k \in K \tag{5}$$

$$R(S_k) - \delta_k^+(R) + \delta_k^-(R) = R^{med} \quad \forall k \in K \tag{6}$$

$$\sum_{k=1}^{|K|} k\left(x_{i,k} - x_{j,k}\right) \le 0 \quad \forall \{i,\ j\} \subseteq J:\ i \in P_j \tag{7}$$

$$\sum_{k=1}^{|K|} k \cdot x_{j,k} \le m \quad \forall j \in J \tag{8}$$

$$\sum_{j=1}^{|J|} x_{j,k} \ge 1 \quad \forall k \in K \tag{9}$$

$$R(S_k), \delta_k^+(R), \delta_k^-(R) \geq 0 \quad \forall k \in K \tag{10}$$

$$x_{j,k} \in \{0,\ 1\} \quad \forall j \in J \wedge \ \forall k \in K \tag{11}$$

The objective function (1) expresses the average absolute deviation of ergonomic risk. Constraints (2) indicate that each task can only be assigned to one workstation. Constraints (3) and (4) impose the maximum limitation of the workload time and the maximum linear area allowed by workstation. Constraints (5) determine the real ergonomic risk associated with the workload at each workstation. Constraints (6) define the ergonomic risk discrepancies, both positive and negative, between the average and real values for each station. Constraints (7) correspond to the precedence task bindings. Constraints (8) and (9) limit the number of stations and force that there is no empty workstation, respectively. Finally, constraints (10) and (11) force the non-negativity of variables and require the assignment variables be binary.

3 Computational Experience

It is performed a computational experiment linked with a case study from Nissan's engine plant in Barcelona (NMISA: Nissan Motor Ibérica), in order to compare the reference model, MILP-1: min-max-R, and the model proposed here, MILP-2: min_AAD-R, that can be considered a specific case of the weighted model formulated in Bautista et al. (2016).

Both models optimize the ergonomic risk considering a fixed number of stations and satisfying the precedence constraints, maximum cycle time and maximum available area; they differ in the optimization criterion. MILP-1 minimizes the maximum ergonomic risk of the line whereas MILP-2 minimizes the distance between the actual ergonomic risk and the desirable average value, balancing the risk as much as possible in all workstations.

For the experience we use a demand plan that consists of a daily global demand of 270 units, which are divided into 9 types of engines grouped into three families: p_1, p_2 and p_3 are engines for crossovers and SUVs; p_4 and p_5 are for vans; and p_6, p_7, p_8 and p_9 are intended for medium tonnage trucks.

The models was solved with the CPLEX (v11.0) software, running on a Mac Pro computer with an Intel Xeon, 3.0 GHz CPU and 2 GB RAM memory under the Windows XP operating system. In all the executions, the CPU time was limited to 2 h for each instance due to temporal conditions imposed by the industrial environment of our case study.

The features of the computational experience are the following:

- It is selected a balanced demand plan (mix 1), whose partial demands are equal for all engine types.
- We analyse different values for the number of workstations. We run the model for the following the rank of values: $m = \{19, 20, 21, 22, 23, 24, 25\}$.

Table 1 Maximum ergonomic risk of the line obtained by MILP-2: min_AAD-R

A	*m (Number of workstations)*						
	19	20	21	22	23	24	25
4	–	–	450	420	375	345	285
5	440	390	320	300	275	265	255
∞	360	315	300	285	275	265	255

Table 2 Maximum ergonomic risk of the line given by MILP-1: min-max-R

A	*m (Number of workstations)*						
	19	20	21	22	23	24	25
4	–	–	375	330	310	280	280
5	–	–	310	300	280	280	275
∞	350	315	300	285	275	270	255

- The maximum cycle time is set by $c = 180\,s$.
- We also analyse the impact of linear area. Indeed we run the model with three values for the maximum available area; these are: $A = \{4,\ 5,\ \infty\}\ m$.

The MILP-2 results, collected in Table 1, show how the maximum ergonomic risk, which corresponds with the station with greater risk, decreases with the increase of number of workstations, for all possible evaluated area values. However, it should be noted that for maximum linear area per station of 4 meters, the model does not find line configurations with 19 and 20 workstations.

When linear area is 4 meters, the maximum risk is 450 e-s[1] and it corresponds with a line with 21 stations, whereas the minimum ergonomic risk found is 285 e-s with 25 stations. When the area is 5 meters, we have the greater maximum risk (440 e-s) with a line configuration of 19 stations and the lower maximum ergonomic risk (255 e-s) with 25 stations. Finally, considering boundless area, we get a line configuration with 19 stations and with the lowest maximum ergonomic risk (360 e-s), but the lower maximum ergonomic risk (that corresponds with 25 stations) is the same than the obtained with the solution with 5 meters (i.e. 255 e-s).

We can state how the area has an important effect on the line configuration. Indeed, when area is not considered ($A = \infty$) the range of the risk, in regard with the number of stations, is 105 e-s (360–255); however, when the maximum allowable area is $A = 5$ meters, the range is 185e-s. Besides, we can see that from 5 meters, the area does not affect the lower maximum ergonomic risk of the line.

Moreover, the results given by MILP-1 are in Table 2.

Table 2 shows the results given by MILP-1 model, that minimizes the maximum ergonomic risk, for the sweep of $m = \{19, 20, 21, 22, 23, 24, 25\}$ and $A = \{4,\ 5,\ \infty\}\ m$. Equally to MILP-2, MILP-1 reduces the ergonomic risk while the number of workstations increases. However, MILP-1 does not find line

[1]The ergo-second is the time unit, measured in seconds, used to assess the ergonomic risk of a task, with a processing time of 1 s at normal work pace, bearing a risk category of 1. Thus, this scale measures the time spent by workers to perform a task (at normal pace) taking into account the level of the ergonomic risk to which they are exposed.

Table 3 Comparative of the results presented by model average absolute deviations of ergonomic risk (MILP-2) and he model of ergonomic risk minimization (MILP-1)

A	*m (Number of workstations)*						
	19	20	21	22	23	24	25
4	–	–	MILP−1	MILP−1	MILP−1	MILP−1	MILP−1
5	MILP−2	MILP−2	MILP−1	IDEM	MILP−2	MILP−2	MILP−2
∞	MILP−1	IDEM	IDEM	IDEM	IDEM	MILP−2	IDEM

configurations with 19 and 20 workstations when the maximum area is 4 meters and neither when the limit is 5 meters. Now, the lower maximum ergonomic risks of a line with 25 stations are 280, 275 and 255 e-s, for area limitations of 4, 5 and infinite meters, respectively. While the greater maximum ergonomic risks (375, 310) are obtained for lines with 21 stations in cases of 4 and 5 meters and for a line with 19 stations for $A = \infty$(350 e-s). In this sense, it is worth highlighting that MILP-1 obtains lower ergonomic risk than MILP-2, when the lines have smallest possible number of stations.

4 Conclusions

Given the importance of determining the best working conditions for workers in actual industrial environments, we have compared two mathematical models to balance assembly lines within temporal, spatial and ergonomic limitations.

The first of them, MILP-1, proposed by (Bautista et al. 2015a), minimizes the maximum ergonomic risk of the line, without considering the differences in risk between stations.

The second model, MILP-2, has been proposed in this paper and it is a specific case from the weighted model by (Bautista et al. 2016). This model is addressed to maximize the ergonomic comfort of the line by the minimization of average discrepancies between the actual risk of stations and the average risk resulting from the set of workstations of the line and the set of operations of the demand plan, which is the value that balances the line regarding risk.

According the results, an increase in the number of workstations leads to a reduction of the ergonomic risk of the line, whatever the model used.

Briefly, Table 3 shows the winner model regardin the maximum ergonomic risk. There, we can observe how the model that minimizes the maximum ergonomic risk (MILP-1), whatever the number of stations, gives better results than the model that minimices average absolute deviations (MILP-2) when the linear area is restricted to 4 meters. When linear area is 5 meters, MILP-2 is better than MILP-1, except when the number of workstations is 21; however, MILP-1 does not reach solution for 19 and 20 workstations. Finally, when the area limitation does not consider, both models provide configurations with the same ergonomic risk, except when the line has 19 stations; in this case MILP-1 wins MILP-2 and 24 stations, where MILP-2 wins MILP-1.

In short, both models provide acceptable results. Even though MILP-1 wins MILP-2 in 7 times, and MILP-2 wins MILP-1 in 5 times, the results of one facing each other are rather similar. Indeed, when the best model is MILP-2 the difference with the result by MILP-1 is lower than 20 e-s.

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Time-Based Conditions for Synchronized Procurement in *Douki Seisan*

Joaquín Bautista-Valhondo and Jordi Fortuny-Santos

Abstract This paper introduces the synchronous manufacturing philosophy (*douki seisan*) devised by Nissan, and relates it to "Just in Sequence", a common technique in current automotive industry. Literature is full of case studies, and the advantages and drawbacks of JIS have been reported. However, no attempt to model the necessary relations to make this system work has been found. In this paper, the necessary conditions concerning the lead times and cycle times of the different activities are deduced, and even the moment when they should take place. They allow us to define a strongly synchronous system. For practitioners, each condition shows opportunities for process improvement. For researchers, lack of compliance with such conditions, gives rise to maximum satisfiability problems.

Keywords Lean manufacturing · Mixed-model assembly line · Just-in-sequence

1 Introduction

The main pillar of the Nissan Production System (NPS) is *douki seisan* (DS) or synchronous manufacturing, a methodology that transfers customers' orders to all processes at same time in order to achieve a continuous and smooth production flow. The requirements of DS for suppliers are similar to those of "Just-in-Sequence" (JIS) delivery: to deliver the required parts, in time, in the necessary quantity and in a pre-determined sequence. If "synchronicity" is about

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time, and all the necessary operations have a certain task time, JIS/DS procurement is only possible if certain time-related conditions are met. The understanding of the logic relations between the tasks implied in JIS procurement might help buyers and suppliers improve the way they work. In this paper we extend the existing literature by exploring and modelling such conditions. The following research questions are addressed: How can we model the JIS/DS relations? Under which time-related conditions synchronous manufacturing and delivery is possible? Which are the elements that allow/impede synchronous delivery.

2 Brief Background

Literature has been reviewed to find previous research on JIT/DS concepts. Although the term JIS is clearly the name is inspired in "just-in-time", the origin of the name is unknown and each company has a different name for it. In spite of earlier developments, it seems to have flourished maybe in the 1990s (Wagner and Silveira-Camargos 2012) and specially at the beginning of the 21st century as a response to the pressure on carmakers related to mass customization of the final product (Sedliak and Šulgan 2011). JIS has experienced great success amongst the premium German automakers who prefer build-to-order manufacturing to build-to-stock manufacturing. However, the importance of Just-in-Time and Just-in-Sequence procurement (as well as the fragile conditions it relied upon) had already been envisaged by H. Ford. Although the advantages and drawbacks of JIS have been studied yet—see Thun et al. (2007)–, none of the reviewed papers analyses JIS/DS in quantitative terms.

In Nissan, *douki seisan* 動 機 生 産 (synchronized flow) is a pillar of Nissan's philosophy since 1960 (Sako 2004). It describes an ideal state where all the processes get information from the customers at same time, in order to establish a continuous flow without changes in the scheduled sequence. When processes have advanced demand information, products can be scheduled and sequenced. Suppliers can be synchronized with the assembly line so they can deliver according to the schedule (Monden 1998).

3 Moments, Lead Times and Cycles: In Search of Synchronicity

The tasks that make synchronous manufacturing and delivery possible are shown in Fig. 1. We assign a time variable to each task to represent its duration.

Let T_s be moment that an OEM (Original Equipment Manufacturer)—the car maker—sends a list with a sequence of T vehicles to a first-tier supplier. For reference purposes, T_c is the current date and time.

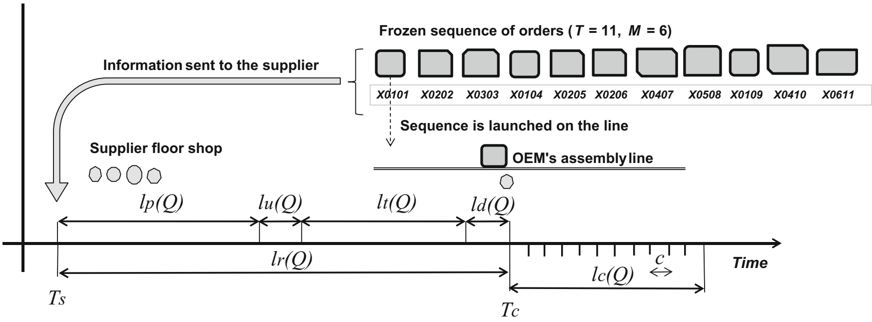

Fig. 1 Representation of the tasks involved in synchronous manufacturing and delivery (JIS/DS). For symbols, please refer to the text (Sect. 3)

Following the notation in Boysen et al. (2009) the planning horizon is divided into T production cycles (with $t = 1;\ldots;T$), with a cycle time c. We may introduce product variability by considering that our final product comes in several models $m \in M$ (where M is a set of models). The demand d_m at the end of the planning horizon is given and has to be met. Each one of the T vehicles in the sequence belongs to a certain model or type. This can be represented by binary variables x_{mt}. If model m is produced in cycle t $x_{mt} = 1$, otherwise $x_{mt} = 0$.

As stated before, at T_s, a purchasing order (Q) of T sequenced units of a certain component Z is placed with a supplier. Because each model of final product needs a specific type of component Z, the purchasing order is the sequenced list of x_{mt} and the quantities demanded per type of component Z_m are exactly d_m.

This order must be ready at the border of the OEM's assembly line (BoL) after $l_r(Q)$ units of time—in consequence, the deadline is $T_s + l_r(Q)$–. We call the supplier's maximum turnaround time (or order lead time) "reaction time" because it is the maximum time allowed to complete the necessary steps to deliver order Q. Nissan's maximum acceptable turnaround time is 6 days.

The supplier's manufacturing lead time $l_p(Q)$ includes setup time, run time and changeover time, which depend on the sequence and also on the production method.

The following step in our model is the order processing lead time $l_u(Q)$ or time necessary, after manufacturing, for order consolidation and time to load the vehicle (or transport system) that has to take the order to the customer. When the order has been loaded onto the vehicle, the order is taken to the customer. Transportation lead time is represented by $l_t(Q)$. Eventually, when the product arrives at the premises of the customer, an additional time $l_d(Q)$ is necessary to unload the vehicle, complete other inbound logistics work and take the sequenced units to the border of the line. There, the T units of the different models of component Z are consumed in $l_c(Q)$ time units. This consumption time depends on T and c as shown in Eq. 1.

$$l_c(Q) = T \cdot c \tag{1}$$

Since these manufacturing and procurement activities are going to take place not once but on a repetitive way over time, we can consider their related cycle times. Thus, we define:

- $c_p(Q)$: Manufacturing cycle time for lot Q. The average time between two consecutive completed orders coming out the end of the manufacturing process under steady state.
- $p_u(Q)$: Vehicle load lead time. The time a vehicle remains parked at the loading dock of the supplier to enable the loading of an order Q.
- $c_u(Q)$: Order load cycle time. The interval of time elapsed between two consecutive lots are loaded in a vehicle. The time difference between two consecutive completions of loading tasks for two consecutive orders.
- $c_t(Q)$: Transfer cycle time. The interval of time elapsed between two consecutive lots are sent to the customer.
- $p_d(Q)$: Vehicle unload lead time. The time a vehicle remains at the dock of the customer to allowing the unloading of an order Q.
- $c_d(Q)$: Order unload cycle time. The interval of time elapsed between two consecutive lots unloaded from a vehicle.

The following conditions are necessary to establish JIS/DS delivery of lot Q:

Condition 1 (Eq. 2): The order lead time, made up of the time spent manufacturing parts $l_p(Q)$, processing the order and loading the truck $l_u(Q)$, transporting the order to the delivery point $l_t(Q)$, and unloading the truck and taking the order to the BoL $l_d(Q)$, must be shorter than, or equal to, the value of $l_r(Q)$ considered by the OEM, otherwise, the order will be late.

$$l_p(Q) + l_u(Q) + l_t(Q) + l_d(Q) \leq l_r(Q) \tag{2}$$

Condition 2 (Eq. 3): When components are supplied from a warehouse (manufacturing is not synchronous), order processing and truck loading $l_u(Q)$ plus transportation $l_t(Q)$ plus truck unloading and inbound logistics tasks $l_d(Q)$ must be shorter than, or equal to, the reaction time $l_r(Q)$. Condition 2 is dominated by condition 1, because if condition 1 is true, condition 2 is always true. For the OEM, Eq. 3 also gives the minimum anticipation required by the system to ensure that the requested sequence of components can be delivered on time. This is the size of the period where no further modifications should be made to the schedule.

$$l_u(Q) + l_t(Q) + l_d(Q) \leq l_r(Q) \tag{3}$$

Condition 3 (Eq. 4): After the present sequence (which takes $l_c(Q)$, the OEM will assemble another sequence of T final products, also with cycle time c, which is the constant pace of the assembly line. A purchasing order Q′ is sent to the supplier with the same anticipation $l_r(Q)$. The supplier will experience the beginning of two order cycles with a delay of $l_c(Q)$ time units. We can conclude that, being $l_u(Q)$,

$l_t(Q)$ and $l_d(Q)$ constant, the time spent in manufacturing $l_p(Q)$ has to be equal to $l_c(Q)$. It means that the supplier is doing at any time what the OEM will be doing $l_r(Q)$ units of time later and so both companies are synchronized.

$$l_p(Q) = l_c(Q) \tag{4}$$

In steady state, and assuming perfect quality, if the supplier manufactures component Z in sequence according to the customer's order, the manufacturing cycle time (without setup or changeover) c_s is equal to the OEM's cycle time c (Eq. 5). If quality was not perfect and there was some idle time for setup and changeover, or different models had different cycle times, then c_s should be measured as the reciprocal of throughput (units per period of time) and would be an average value over lot Q.

$$l_p(Q) \leq l_c(Q) \Rightarrow T \cdot c_s \leq T \cdot c \tag{4}$$

$$c_s \leq c \tag{5}$$

Other necessary conditions are:

Condition 4: Manufacturing cycle time for lot Q must be shorter than or equal to the order load cycle time (Eq. 6). The opposite is impossible, because the second process depends on the first one. For example, if orders are finished every two hours, it is not possible to completely pack such orders and load them into trucks every hour, because there are no parts available. This phenomenon is known as process starvation (Bai and Gershwin 1995).

$$c_p(Q) \leq c_u(Q) \tag{6}$$

Condition 5: Vehicle load lead time must be shorter than or equal to the order load cycle time (Eq. 7).

$$p_u(Q) \leq c_u(Q) \tag{7}$$

If every $c_u(Q)$ time units an order has to depart, it is impossible to spend more than $c_u(Q)$ time units loading a vehicle. Otherwise, the next vehicle would have to wait. Equation 8, which is equivalent to Little's Law (Little 1961), gives the average number of vehicles at the dock.

$$\textit{Average number of vehicles at the supplier's dock} = p_u(Q)/c_u(Q) \tag{8}$$

Condition 6: The order load cycle time must be equal to the transfer cycle time (Eq. 9). This relation is clearer if frequencies are used instead of cycle times (cycle and frequency are reciprocal values): The number of trips per time unit must be equal to the number of vehicles that are loaded per time unit.

$$c_u(Q) = c_t(Q) \Leftrightarrow v_u(Q) = v_t(Q) \tag{9}$$

Condition 7: Vehicle unload lead time must be shorter than or equal to order unload cycle time (Eq. 10). For the same reason that explains condition 5. We can also compute the average number of vehicles at the customer's dock (Eq. 11).

$$p_d(Q) \leq c_d(Q) \tag{10}$$

$$Average\,number\,of\,trucks\,at\,the\,customer's\,dock = p_d(Q)/c_d(Q) \tag{11}$$

Condition 8: The transfer cycle time must be equal to the order unload cycle time. After conditions 6 and 8, we can write Eq. 12, expressing the continuity of the delivery cycle: in steady state, the number of vehicles that are loaded per time unit is the same that the number of vehicles that travel to the customer's premises and is the same that the number of vehicles that are loaded.

$$c_u(Q) = c_t(Q) = c_d(Q) \Leftrightarrow v_u(Q) = v_t(Q) = v_d(Q) \tag{12}$$

Condition 9: The order unload cycle time must be shorter than or equal to the time in which lot Q is consumed by the customer $l_c(Q)$ (Eq. 13). If $c_d(Q) = l_c(Q)$, there is a container or truckload for each sequenced order, although this equation alone does not explain whether the order is on time or it is late. The delivery is late if $c_d(Q) > l_c(Q)$. Following Little's law once more, the relationship between $l_c(Q)$ and $c_d(Q)$ gives the average number of orders of component Z, at the customer's, being unloaded from trucks and taken to the BoL during the assembly process (Eq. 14).

$$c_d(Q) \leq l_c(Q) \tag{13}$$

$$Average\,number\,of\,orders\,BoL\,per\,sequence = l_c(Q)\,/c_d(Q) \tag{14}$$

If we consider previous equations together, we connect the supplier with the OEM (Eq. 15).

$$c_p(Q) \leq c_u(Q) = c_t(Q) = c_d(Q) \leq l_c(Q) = T \cdot c \tag{15}$$

Finally, if $c_p(Q) = l_p(Q)$, which means that only one order is processed at a time, we get Eq. 16.

$$l_p(Q) = c_p(Q) \leq c_u(Q) = c_t(Q) = c_d(Q) \leq l_c(Q) = T \cdot c \tag{16}$$

Definition

A manufacturing and delivery system is said to be strongly synchronous (Eq. 17) when the supplier's manufacturing cycle time of an order coincides with the order load cycle (which in turn coincides with transfer cycle time and order unload cycle time) and the supplier's manufacturing lead time and the time the customer needs to incorporate the supplies in its final products.

$$l_p(Q) = c_p(Q) = c_u(Q) = c_t(Q) = c_d(Q) = l_c(Q) = T \cdot c \quad (17)$$

Equation 17 describes the ideal state where idle times and wait times have been removed from the system and therefore it achieves its maximum efficiency. In practice, all deviations from this ideal state—*DS*—mean that the system only reaches a certain degree of synchronicity. Previous conditions offer directions for system improvement: practitioners have to act upon the elements (i.e. material, machines, technology, methods, information…) that lie behind each one of the terms that have been mentioned in conditions 1 to 9.

Condition 10: The amount of transportation units $u_t(Q)$ (vehicles such as trucks or autonomous automatic guided vehicles AGVs, slots in a conveyor belt, and so on, depending on the environment of each case) necessary to accomplish the deliverance process is related to the following concepts: vehicle load lead time $p_u(Q)$, transportation lead time $l_t(Q)$, vehicle unload lead time $p_d(Q)$ and transfer cycle time $c_t(Q)$ as shown in Eq. 18, where $\lceil \cdot \rceil$ is the ceiling function.

$$\lceil (p_u(Q) + 2 \cdot l_t(Q) + p_d(Q)) / c_t(Q) \rceil \leq u_t(Q) \quad u_t(Q) \in \mathrm{Z} \quad (18)$$

4 Conclusions

JIS has been developed as an answer to the variability of parts caused by the increasing customization of vehicles. Nissan Production System has always been based on synchronicity and therefore Nissan tries to extend its synchronous manufacturing and delivery strategy (*douki seisan)* to selected suppliers, facing the same situation that other companies that have implemented JIS lately.

In this paper, the synchronous manufacturing and delivery system between an OEM and a supplier has been modelled and up to 18 equations and 10 conditions have been developed to show necessary relations among the moments when some events take place, the amount of time spent in certain tasks and the cycle time of repetitive processes. Lack of compliance with such equations results in failure of the system. Research findings can help practitioners reduce the amount of time spent in a task or develop a more robust system. They should consider the agents and elements involved in each magnitude (E.g. time spent in order consolidation after manufacturing) and act upon them. However, investment in resources should take into account the relationships between processes shown in the proposed equations because otherwise improving a certain task might not lead to the desired improvement in the performance of the system. When the system reaches the condition described in Eq. 17, with no delays, no idle time and no late deliveries, the system is strongly synchronous.

Some directions for further research: (i) A synchronicity measurement index (SMI) should be developed to measure the situation of a company in the maturity path towards DS. (ii) Conditions given in this paper describe a set of constraints necessary to achieve synchronicity. Companies may have to choose to satisfy as many constraints as possible, taking into account the economic implications of doing so. This would be modelled as a maximum satisfiability (MAX-SAT) problem.

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An Overview of Optimization Models for Integrated Replenishment and Production Planning Decisions

Arturo Orbegozo, Beatriz Andres, Josefa Mula, Matthieu Lauras, Carlos Monteiro and Miguel Malheiro

Abstract This paper presents a summary of a review of optimization models for integrated production and replenishment planning decisions. To deal with this research, current approaches addressing replenishment and production planning are reviewed, and compared with the enterprises requirements, willing to collaboratively perform both processes. This research is embedded in the H2020 C2NET research project. The enterprises requirements are extracted from the industrial Pilots participating the C2NET project. This paper will provide researchers and practitioners a starting point for optimization models in the replenishment and production area in the collaborative context.

Keywords Optimization models · Replenishment · Production · Planning decisions

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1 Introduction

Traditionally, replenishment and production planning decisions in supply networks have been made sequentially and independently. The usual way to proceed is to deal first with the production planning, and second, to compute the material/components required to produce the computed quantities of each finished good, given concrete demand in a determined planning horizon. Nevertheless, enterprises are currently embedded in highly dynamic and globalized environments. In order to guarantee the firms competitiveness, and the increase and maintain the customers' service level the establishment of collaborative processes among the enterprises of the same network is a key of success.

This paper analyses, first, some of the contributions proposed in the literature as regards the replenishment planning models. Secondly, the papers addressing the integration between replenishment and production plans are examined. Concluding that, the simultaneous consideration of replenishment of production planning activities in an integrated way may lead to increased efficiency and cost savings, increasing the sustainability and stability of the relationships established by the enterprises belonging to the collaborative networks.

The work developed in this paper is framed in C2NET H2020 project (2015–2017) which is directed towards the development a cloud platform that consist of, optimization tools, collaboration tools to support and agile management of the collaborative network, specifically focusing on small and medium enterprises (SMEs) (Andres et al. 2016).

Currently, the European SMEs do not have access to advanced management systems and collaborative tools in the context of collaborative replenishment and production, because of their limited resources (European Commission 2005). Therefore, ubiquitous tools are needed to support collaboration between different entities in the value chain and offer advanced algorithms to achieve global and local optimization of manufacturing processes and respond more quickly and efficiently unforeseen changes. C2NET objective is based on the creation of cloud tools to support optimization of manufacturing networks composed mainly of SMEs and their logistic assets through demand management, production and supply plans, considering the Collaborative Network perspective.

In order to present an overview of the optimization models for integrated replenishment and production planning decisions, this paper is organised as follows: Sect. 2 it is presented C2NET project and the main contributions that will be obtained throughout its development; focusing on the Metalworking pilot, belonging to the metalworking sector. In Sect. 3 a summary of the integrated replenishment and production planning models is provided and the gaps between the literature and the industry are framed. Finally, Sect. 4 discusses the conclusions.

2 Metalworking Pilot C2NET Project

C2NET project has the purpose to validate the developed solutions, derived from the research, in industries. Accordingly, four industrial Pilots are described in the project, considering different industrial sectors (automotive, dermo-cosmetics, metalworking, and hydraulic and lubrication systems). In order to gather the enterprises needs in terms of replenishment and production plans, this paper focuses on Metalworking pilot. The identification of industrial needs, is therefore, based on characteristics of the Metalworking pilot, studying the needs that the enterprises have in their replenishment and production plans. The research work will be focused on identifying the degree of coverage that the current industrial plans (identified in Metalworking pilot) have in the literature and how theoretical proposals and models deal with the integration of replenishment and production plans, knowing the relevance of its collaborative application.

More specifically, Metalworking pilot is focused on the sheet metal supply chain to metalworking industry, composed by three SMEs. For confidentiality reasons, the names that are used throughout this paper to allude companies are fictitious. *Enterprise 1* assumes the role of an industrial park manager with a mission of promoting science & technology connection with business society, contributing to regional development by improving the competitiveness of organizations and increase the skills of individuals. *Enterprise 2* corresponds to an SME focused in the production of seamed steel tubes, whose recent investments were mostly made towards increasing the production capacity. The company also offers mechanical operations according to the needs of theirs customers and to add value to the product itself. *Enterprise 3* is an SME focused in stamping aluminium, steel components and wire bended as well. It has a market range from the automotive industry, to footwear, hand tools manufacturers or textile industry. Despite not being part of the same supply chain, both SME's are willing to collaborate through the a regional park manager and use the C2NET platform to optimize their logistic management and share the resources to receive raw material and/or ship final products.

Metalworking pilot applies the C2NET platform, to improve the management of logistic resources, namely transportation and storage. Companies use the C2NET to identify collaboration opportunities in replenishment and production planning as well as to formalize a clear vision of the collaborative situation, defining common processes that could be shared throughout the sheet metal value chain. C2NET acquires information regarding resources needs and consumption, or in the warehouses and transportation vehicles to acknowledge exactly were certain materials are located. This provides relevant knowledge to enable the C2NET platform to supervise the collaborative status of the partnerships, and allow to optimize logistics assets and shared processes.

3 Integrated Optimisation Models

In the optimisation field, is important to highlight the work performed by Karni (1981), where the use of integer programming for solving MRP problems is justified. The search for papers, which consider, on the one hand, optimization models for addressing replenishment plans, and on the other hand, optimization algorithms to deal with the collaborative replenishment and production planning decisions was performed using the Sciverse Scopus database. As regards supply chain management, APS was developed (Stadtler and Kilger 2002; Chopra and Meindl 2004; Kreipl and Pinedo 2004) in order to combine MRP with capacity requirement planning to look for the creation of feasible production plans. Moreover, optimization algorithms and simulation approaches have been proposed to bridge the gap theoretical optimization techniques, and replenishment-production planning problems in collaborative networks.

3.1 Replenishment Planning

Replenishment planning deals with the Plan Source (S) identified in the SCOR views (Supply Chain Council 2012), focusing on the computation of the amount of items to be ordered per periods in a planning horizon. The main input data is the material needs, calculated via classical stock management (e.g. EOQ) or via the production plans (e.g. MRP). The replenishment will use limited resources of the supplier. Replenishment plans can be arranged considering four different levels of production:

- S/Inventory Planning: Plan that deals with the inventory management in the procurement of raw materials, finished goods and/or distribution goods in supply chains to meet optimal inventory parameters that must be maintained, to meet expected service levels for demand fulfilment;
- S/Procurement Planning: Plan that deals with the procurement management of a buyer who needs to purchase a variety of goods from its suppliers, to meet planned or actual demands;
- S/Material Requirements Planning: Plan that translates a production schedule of a finished product into a known quantity and timing needs for components based on bill-of-material and lead-time information;
- S/Replenishment Planning: Plan used to calculate inventory replenishment policies taking into account variation in customer demand and replenishment order lead times.

In order to perform the state of the art of replenishment planning models, a matching among industrial plans needs and the existing literature has been carried out in the Metalworking pilot, of C2NET project. The matching has been achieved by comparing parameters between the considered industrial plans and those collected from literature. Three kinds of parameters have been used for this comparison: (1) input data, parameters related with the information needed to optimize the plan; (2) objectives, to identify the expected optimization criteria and (3) output data, parameters related with the expected result of the optimization. Focusing in Metalworking pilot, Table 1 matches the input data (Id_i) parameters, objectives (O_j) and output data parameters (Od_k) needed, with models and algorithms identified in the literature. If the literature model uses the same Id_i, O_j or Od_k than the industrial plan an "X" is scored; if not a gap is founded. The type of algorithm column shows the algorithms used for dealing with Source Plans. The analysed papers have its main concern on proposing optimisation algorithms (AO) and metaheuristic algorithms (AM).

3.2 Integrated Replenishment and Production Planning

Source & Make (SM) Plan deals with the procurement of goods and services and transforms products into finished goods to meet planned or actual demands. Metalworking pilot defined in C2NET proposes the collaborative plans regarding:

- S/Materials Requirements Planning & M/Production Planning: Production planning in a capacity constrained Material Requirements Planning (MRP). The main goal is to determine the Master Production Schedule (MPS), that specifies the quantity to produce of each final product in every period of the planning horizon and the planned ordering of raw materials and components of the MRP, stock levels, delayed demand, and capacity usage levels, in each period, over a given planning horizon;
- S/Inventory Planning & M/Production Planning: Planning model where sourcing considerations are important, given that products can be manufactured at several facilities. Optimal allocation of assets to production tasks in order to satisfy the fluctuating demands over an extended horizon.

In the same way that has been made for source plans (Table 2), a matching among industrial integrated replenishment and production planning needs for Metalworking pilot and the existing literature has been performed. The results are shown in Table 2. Table 2 follows the same structure as Table 1 but considering the literature plans that address collaborative replenishment-production planning.

Table 1 Matching between metalworking pilot industrial needs and source literature plans

Metalworking pilot	Input data								Objectives				Output data				Algorithm type
Plans needs	Id_1	Id_2	Id_3	Id_4	Id_5	Id_6	Id_7	Id_8	O_1	O_2	O_3	O_4	Od_1	Od_2	Od_3	Od_4	
Billington et al. (1983)	X	X	X	X	X	X			X		X		X			X	AO/Simplex
Rota et al. (1997)	X	X	X			X			X			X	X				AO/Simplex
Serna et al. (2009)	X								X				X				AM/Genetic Algorithm
Narmadha et al. (2010)		X							X						X		AM/Genetic Algorithm
Valencia and Cáceres (2011)		X							X				X		X		AM/Genetic Algorithm
Okongwu et al. (2012)	X	X					X			X		X	X	X		X	AO/Branch and Bound
Yang et al. (2012)	X							X	X	X							AM/Genetic Algorithm
Liu et al. (2013)		X							X						X		AM/Iterated Local Search
Mula et al. (2014)	X	X				X	X		X	X			X		X		AO/Simplex
Deng et al. (2014)		X				X		X		X			X				AM/Simulated Annealing
Ab Rahman et al. (2015)	X									X			X				AM/Genetic Algorithm

Id1 Demand, *Id2* Inventory, *Id3* Capacity, *Id4* Production Time, *Id5* Setup, *Id6* BOM, *Id7* Lead time of supply, *Id8* Supplier Prices
O1 Inventory cost min, *O2* Profit max, *O3* Idle time min, *O4* Backorders min
Od1 Components to purchase, *Od2* Backorders, *Od3* Inventory, *Od4* Delivery time

Table 2 Matching between metalworking pilot needs and SMD literature plans

Metalworking pilot	Input data								Objectives						Output data					Algorithm type
Plans needs	Id_1	Id_2	Id_3	Id_4	Id_5	Id_6	Id_7	Id_8	O_1	O_2	O_3	O_4	O_5	O_6	Od_1	Od_2	Od_3	Od_4	Od_5	
Mcdonald and Karimi (1997)	X	X	X	X		X		X		X			X	X	X	X			X	AO/Simplex
Mula et al. (2006)	X	X	X	X		X			X		X	X	X		X	X			X	AO/Simplex

Id1 Demand, *Id2* Inventory, *Id3* Capacity, *Id4* Production Time, *Id5* Setup, *Id6* BOM, *Id7* Lead time of supply, *Id8* Supplier Prices
O1 Inventory cost min, *O2* Profit max, *O3* Idle time min, *O4* Backorders min, *O5* Production cost min, O6 Transport cost min
Od1 Components to purchase, *Od2* Backorders, *Od3* Inventory, *Od4* Delivery time, *Od5* Products to produce

4 Conclusions

This work has addressed the optimization models for integrated replenishment and production planning decisions considering its importance in the collaborative context. The analysed papers are characterised by dealing, on the one hand, with replenishment planning and, on the other hand, the integration between replenishment and production plans. These plans are compared with the real requirements collected from industry. In this regard, the industrial needs are collected from the Metalworking pilot, of the C2NET project. According to the results obtained in the review, the integrated replenishment-production process is a challenging area of research, in order to match the industry needs with the proposals developed in the academia. The results obtained in the work, of comparing replenishment-production literature plans with industrial needs, highlight that current works addressing replenishment-production plans do not completely feet the requirements defined by the industry. Therefore, the proposal of new algorithms to deal with the industrial requirements, not currently solved in the literature, has been identified. These new algorithms should take into consideration all the inputs, outputs and objectives defined by the enterprises. In this regard, the design of effective optimisation algorithms, which can obtain good quality solutions in a reasonable running time, is identified as a future research line for the development of optimisation approaches given their possible impact on industrial implementation. Moreover, a deeper analysis will be held for identifying industrial needs not only in the metalworking industrial sector but also in other relevant manufacturing industries, such as automotive, dermo-cosmetics, hydraulic and lubrication systems, tiles, textile, furniture, machinery, plastics, etc.

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Optimization Models to Support Decision-Making in Collaborative Networks: A Review

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Abstract Enterprises, especially SMEs, are increasingly aware of belonging to Collaborative Networks (CN), due to the competitive advantages associated to deal with markets globalization and turbulence. The participation in CN involves enterprises to perform collaborative planning along all the processes established with the CN partners. Nevertheless, the access of SMEs to optimisation tools, for dealing with collaborative planning, is currently limited. To solve this concern, novel optimisation approaches have to be designed in order to improve the integrated planning in CN. In order to deal with this problem, this paper proposes a baseline to identify current enterprise needs and literature solutions in the

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replenishment, production and delivery collaborative planning, as a part of the H2020 Cloud Collaborative Manufacturing Networks (C2NET) research project. The main gaps found between the literature reviewed and the enterprises' needs are presented and discussed.

Keywords Collaborative networks · Collaborative processes · Production planning · Industrial optimisation needs

1 Introduction

Collaborative networks are embedded in continuously changing environments that affect to demand changes, disruptions, uncertainties, etc. Internal enterprises plans and collaborative planning is affected by these changes. The main goal of current research is to provide appropriate optimisation and automated approaches to deal with the collaborative planning, providing affordable solutions to SMEs willing to collaborate. To this regard, the identification of contributions, provided in the literature, is considered a first step to perform in order to identify adequate algorithms and simulation procedures that allow SMEs to collaboratively establish replenishment, production and delivery planning processes. Affordable tools (in terms of cost, usability, light weight and easy to use tools) are required to help SMEs to overcome the current economic crisis and to enhance their competitiveness in the global economy.

The work described in this paper is framed in C2NET H2020 project (2015–2018) that will implement a Cloud Platform for supporting the SMEs supply network optimisation of manufacturing and logistic assets based on collaborative demand, production and delivery plans. C2NET Project will provide a scalable real-time architecture, platform and software to allow the supply network partners to (i) master complexity and data security of the supply network, (ii) store and share product, process and logistic data, (iii) optimise the manufacturing assets by the collaborative computation of production plans, (iv) optimise the logistics assets through efficient delivery plans and (v) render the complete set of supply chain management information on the any digital mobile device (PC, tablets, smartphones) of decision makers enabling them to monitor, visualise, control, share and collaborate.

To cope with the objective of this paper, the paper is organised as follows: Sect. 2 introduces the C2NET project, focusing on the automotive pilot, belonging to the automotive sector. In Sect. 3 a state of the art of the contributions addressing the replenishment, production and distribution collaborative planning is given. The review will allow identifying the gaps between the literature and the industry real needs. Finally, Sect. 4 discusses the conclusions.

2 Automotive Pilot in Cloud Collaborative Manufacturing Networks Project

C2NET project has the purpose to connect the Industrial, the Research and the Development perspectives. To this end four industrial Pilots are considered in the project, belonging to different industrial sectors (automotive, dermo-cosmetics, metalworking SMEs and OEM production of hydraulic and lubrication systems). This paper is going to focus in Automotive Pilot to study the needs that the enterprises belonging to this pilot have in their production plans, and how the literature plans cover the potential integration of collaborative replenishment, production and delivery plans.

The automotive pilot is framed in the automotive industrial sector and deals with collaborative production planning and synchronised replenishment of car components. The studied pilot consists of the first and second-tiers fully dedicated tot the car assembly. The first-tier supplier will use the C2NET cloud infrastructure, platform and software to perform collaborative production, replenishment planning and capacity shared with the second-tier suppliers of materials for car interior components to be supplied to the OEM. Enterprises of automotive pilot will share relevant information and will use the C2NET advanced algorithms to optimise production, supply and replenishment plans.

The automotive pilot takes as main input the 6 months demand release, the 7 days massive and the daily call-in (DCI) sent by the OEM to the first-tier. Considering these inputs, C2NET optimisation and simulation algorithms will automatically calculate (i) the first-tier car components production plans, and (ii) the first-tier parts requirements planning, which are the input for the Demand Plan of second-tier. Taking into account the second-tier capacities and current stock levels, C2NET will calculate the second-tier parts production plans and the materials requirements planning with the goal of optimising the manufacturing and logistics assets. Production, replenishment and distribution plans will be calculated with the goal of optimising the logistics assets of automotive pilot. C2NET will provide online re-calculations when changing market conditions or manufacturing situations and continuously update the plans taking into account the actual or current production, stocks and deliveries status.

The current research work allows identifying the gaps between the literature contributions and the automotive pilot needs, regarding the establishment of collaborative plans to support the decision-making in the establishment of collaborative source, make and delivery processes along the supply network (see Fig. 1).

From the collaborative manufacturing and logistics processes identified in the enterprises belonging to the automotive pilot of C2NET project, a thorough review of current state of art of optimisation algorithms and simulation procedures used to solve related manufacturing processes problems, especially in the frame of collaborative processes, is made. As a result of this activity, a deep understanding of the different optimisation and simulation approaches existing in the literature is

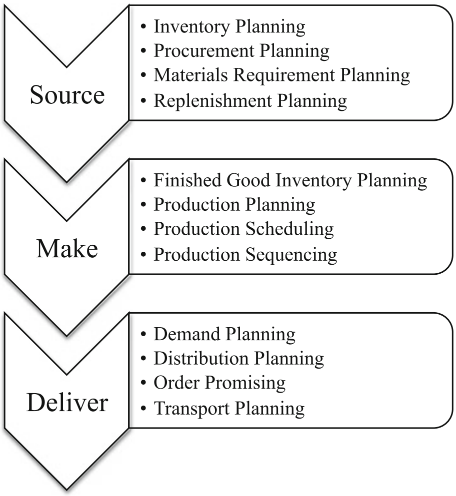

Fig. 1 SCOR classification for industrial plans (based on: Supply Chain Council 2012)

obtained. This knowledge will be considered as the main input to identify the gaps between the enterprises needs when dealing with their plans and the contributions that propose the literature to overcome this needs.

3 Collaborative Network Processes Optimisation

Research in optimisation solutions has been a very active field in the last decades. One of the most successful application areas has been the planning and scheduling of operational manufacturing processes, trying to optimise cost, resource allocation, delivery time, etc. Authors such as Billington et al. (1983), Escudero (1994), McDonald and Karimi (1997), Karimi and McDonald (1997), Rota et al. (1997), Clark (2003), Giglio and Minciardi (2003), Chen and Lee (2004), Lim et al. (2005), Yenisey (2006), Noori et al. (2008) and Alemany et al. (2010), among others, have addressed the optimisation of production systems through different mathematical programming approaches in a deterministic context. In addition, intelligent modelling and heuristic modelling approaches have been proposed as bridging techniques between the problems that theoretical optimisation techniques can handle and real world problems. Hernandez et al. (2014) developed multi-agent negotiation based algorithms to support the collaborative supply chain planning process using intelligent modelling and heuristic modelling approaches. Here, those based on fuzzy mathematical programming models (Mula et al. 2010) have been developed for production planning problems under uncertainty. For an extensive review, Mula et al. (2006) is interesting reference in this field.

Which kind of technique is better for what kind of problems is controversial and is the source of much research. Real-life enterprise optimisation problems, as for example planning and scheduling, often need both linear and non-linear constraints and may involve hundreds/thousands of (real/integer/binary) variables and constraints, and are difficult to tackle with generic algorithms.

3.1 Production Planning: Make

Production planning is associated with the plan Make view identified in the SCOR views (Supply Chain Council 2012), and deals with the amounts of items to be produced per periods in a planning horizon. The main input data is the demand (customers orders or demand forecast). The production use limited own resources, which will define the solutions space. The goal is to obtain Production Plans, which minimise or maximise selected objectives. Production plans can be arranged considering three different levels of production (Fig. 1):

- Make/Production Planning: Plan that deals with the allocation of assets to production tasks, determine the quantity of production, inventory and work force levels in order to satisfy the planned or actual demand. Production planning concerns the required level of production in a specified time horizon;
- Make/Production Scheduling: Given a set of due dates, demands for products at these dates, and several operational and topological constraints, this Plan deals with the start and end times of individual products and machine assignments. Scheduling model includes lot sizing models and machine scheduling models. Production scheduling concerns the allocation of finite resources to meet the demand requirements, paying heed to constraints such as capacity, precedence and start and due dates;
- Make/Production Sequencing: Plan that deals with the resource level ordering of jobs on a shared workstation. Production Sequence Plan is dependent of sequence setup costs and impossible restrictions in terms of the order of jobs.

Table 1 presents the matches between the Automotive industrial pilot optimization needs and Make plans found in literature. Each row presents a reference with industrial optimisation case and algorithm. Inputs were classified in six input data (Id_i) types: Id_1: Demand, Id_2: Inventory, Id_3: Capacity, Id_4: Production Time, Id_5: Set-up and Id_6: Bill Of Materials (BOM). Objectives were arranged (O_j) into three types: O_1: Production cost minimisation, O_2: Profit maximisation, O_3: Setup minimisation. Finally, the outputs (Od_k) were groped in four classes: Od_1: Products to produce, Od_2: Backorders, Od_3: Machine assignation and Od_4: Extra time. Each *X* in the table represents a match between the industrial optimisation parameter and algorithm in literature. The algorithm types considered are classified considering the following taxonomy: AO optimisation algorithm, AM metaheuristic algorithm and AH heuristic algorithm.

Table 1 Mapping between Pilot 1 optimisation needs and make plans in the literature

Automotive pilot	Input data						Objectives			Output data				Algorithm type
Plans needs	Id_1	Id_2	Id_3	Id_4	Id_5	Id_6	O_1	O_2	O_3	Od_1	Od_2	Od_3	Od_4	
McDonald and Karimi (1997)	X	X	X		X	X	X	X		X	X			AO/simplex
Escudero (1994)	X	X	X	X		X		X		X	X			AO/decomposition strategy
Gupta and Magnusson (2005)	X	X	X		X				X	X				AO/simplex
Franz et al. (2014)	X			X						X		X		AM/tabu search
Gansterer (2015)	X	X	X	X		X				X	X			AH/variable neighbourhood search

Table 2 Mapping between automotive pilot optimisation needs and SMD plans in the literature

Automotive pilot	Input data								Objectives				Output data						Algorithm type
Plans needs	Id_1	Id_2	Id_3	Id_4	Id_5	Id_6	Id_7	Id_8	O_1	O_2	O_3	O_4	Od_1	Od_2	Od_3	Od_4	Od_5	Od_6	
Sabri and Beamon (2000)	X	X	X	X		X	X		X			X	X				X	X	AO/strategic-operational optimisation
Alemany et al. (2010)	X	X	X	X	X	X					X	X	X	X			X	X	AO/simplex

3.2 Replenishment, Production and Distribution Collaborative Planning

Source & Make & Deliver (S&M&D) plan is characterised the integration of plans, of the collaborative network partners, that deals with (i) the procurement of goods and services, by computing the amount of items to be ordered per periods in a planning horizon considering the material needs, the limited resources of the supplier (ii) the transformation of products into finished goods and (iii) the distribution of finished goods and services to meet planned or actual demands, computing the amount of items to be delivered per periods in a planning horizon considering the customers' orders, and the delivery limited resources (own, from the customer or from a third party). Automotive pilot proposes the envisioned collaborative plan regarding S/Replenishment & M/Production Planning & D/Distribution Planning to deal with sourcing considerations for replenishments, production facilities, and distribution centres, over the time periods of the planning horizon. Inputs were classified in eight input data: Id1 Demand, Id2 Inventory, Id3 Capacity, Id4 Production Time, Id5 Setup, Id6 BOM, Id7 Transport batch minimum Id8 Transport Capacity. Objectives were arranged (O_j) into four types: O1 Production cost min, O2 Profit max, O3 Setup min, O4 Transport/distribution cost min. Finally, the outputs (Od_k) were groped in six classes: Od1 Products to produce, Od2 Backorders, Od3 Machine assignation, Od4 Extra time, Od5 Raw material to purchase, Od6 Product quantity to transport. Allocation decision of final goods to production lines are defined with a limited capacity, but also with the determination of lot sizing. Following the structure defined in Table 1, Table 2 presents the mapping between the industry optimisation needs and the combined replenishment, production and distribution plans found in literature.

4 Conclusions

The main aim of this paper is to support manufacturing networks in the optimisation of manufacturing and logistic assets by the collaborative calculation of production plans, replenishment plans and delivery plans in order to achieve shorter delivery times, better speed and consistency of schedules, higher use of productive resources and energy savings. To study this, the needs identified by the enterprises belonging to Automotive pilot were identified in two contexts: (i) considering uniquely the computation of the production plan (Make, M), and (ii) the computation of source, make and delivery collaborative plans (SMD). On the other hand, the performed state of the art has allowed identifying how the contributions proposed in the literature cover the industrial needs, in terms of computing manufacturing and logistic plans. In this regard, a set of gaps have been found in the form of non-covered industrial optimisation needs. The non-covered needs, identified with the mapping task, must be addressed when developing, in future research, novel optimisation algorithms. The most matching optimisation algorithms found in the literature will be used as a base for the implementation of the novel algorithms, which will fulfil the needs of industrial optimisation cases.

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Petrobras' Investment Projects in Brazil Under Checkmate: The Ghost Refineries Case

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Abstract Brazil's oil production has been growing steadily. In 2005/2006 it was publicly claimed that Brazil had reached its self-sufficiency. Currently, we know that it refers to volumetric self-sufficiency, considering the absolute figures of supply and demand. Broad self-sufficiency also requires the adjustment of Brazilian refineries to oil that is 100% national, and this is where the refining sector comes in. The main goal of this article is to analyze the alleged self-sufficiency regarding petroleum products for Brazil, considering a hypothetic scenario on which all of the investments planned by Petrobras in 2014 for the refining sector are 100% operational. Economic growth projections related to oil production and demand curves, in addition to the technical characteristics of the national refining park, allow us to evaluate the actual status of a wider self-sufficiency. On this hypothetical scenario, self-sufficiency is reached, in volumetric terms, by 2018, through projections made by OPEC and Petrobras. However, the start of operations of four huge investments announced in 2014 (Rnest, Comperj, Premium I and Premium II) is not enough to reach the self-sufficiency in oil derivatives, even in the most conservative scenario, with low economic growth rates. This shortcoming will affect mostly gasoline, which curiously has no part on the investments planned by the company on the coming years. The current outlook, added to the projections, suggests the possibility of the existence of a strong technological downgrade on the oil sector. We conclude with a warning about the urge for new investments on the national refining sector, aiming the production of high value-added products.

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Keywords Brazil · Self-sufficiency · Pre-salt · Refining · Oil derivatives

1 Introduction

Since the discovery of Brazil's pre-salt layer, a lot has been said about the country's self-sufficiency in petroleum. At the end of 2005 it was publicized the country's self-sufficiency in volume, since the availability of petroleum extracted from national fields matched up to its consumption and refining capacity to reach the demand of the Brazilian market (Petrobras 2005). However, after the economic crisis between 2008 and 2009, the government started a deep tax incentive program reducing automobiles sales taxes and freezing gasoline and diesel oil prices. These economic measures resulted in a demand increase, which led to a significant trade deficit in crude oil, and on refined goods.

Nevertheless, with the beginning of the production on pre-salt wells, huge investments were planed to the refining sector. Petrobras publicized, in 2014, a projection for Brazil's self-sufficiency regarding petroleum derivatives due to 2020, being that in 2016 there would be a volumetric self-sufficiency again, after ten years (Petrobras 2014).

This article's main goal is to analyze Brazil's self-sufficiency on derivatives, based on a hypothetic scenario on which all the investments planned by Petrobras in 2014 to the refining sector were to be fully operational, considering distinct scenarios on national derivatives production and demand. As a secondary goal, this paper suggests which refineries are the best targets to the volume extracted from pre-salt fields and whether there is a possibility on Brazil becoming a petroleum derivatives exporter. The main parameters used in the analysis were the utilization factor, oil products production shares on each of the refineries, logistics and national market demand and supply curves. The time-span goes from 2014 to 2020, and the main sources of data were: Organization of the Petroleum Exporting Countries (OPEC); National Agency of Petroleum, Natural Gas and Biofuels (ANP); Ministry of Mines and Energy (MME) and Petrobras.

At the first section of the article, the refining sector scenario is presented. The second section presents an analysis on the national refining park idle capacity and on which refineries will be the main targets to oil produced on pre-salt layers. Last, we discuss self-sufficiency, both volumetric and regarding derivatives, confronting different projections on demand and production.

2 The National Refining Sector

The current Brazilian refining park consists on seventeen refineries, thirteen owned by Petrobras and four by private companies. These refineries are already operating in Brazil, in spite of the obstacles inherent to the sector. The problem faced by

Petrobras on its refining activities is the high utilization factor of its refineries: in 2015, the number was around 77.5% (ANP 2016). Regardless of the fall in comparison to 2014, when the factor was about 98%, this current value still represents a "bottleneck", since the fall was due to a shortening on internal market's demand and Abreu e Lima Refinery's (Rnest) operation, for its refining capacity was kept, during 2015, only on 74 thousand bbl/d, because of a limitation stablished by the Environmental Agency of the state of Pernambuco.

By contrast, the obstacle faced by all the refineries held by private companies is getting the raw material and keeping its products prices in a competitive baseline when compared to the ones from Petrobras refineries. With the entrance of pre-salt oil in the market, it will be easier for these companies to get national feedstock and fill their idle capacity, clearly displayed by their low utilization factor, which was around 46.2% in 2015 (ANP 2016).

To build the ideal scenario, three refineries were added to that amount: they are part of the Business and Management (Petrobras 2014) plan of the main national company and of crucial importance on reaching the derivatives self-sufficiency predicted for 2020.

One of the main projects planned by Petrobras in 2006 but still under construction is the Rio de Janeiro Petrochemical Complex (Comperj). When concluded, the total capacity of this plant will be 165 thousand bbl/d (ANP 2016). The refinery's main products will be diesel, petrochemical naphtha, aviation fuel, petroleum coke, liquefied petroleum gas (LPG) and fuel oil; products highly present on Brazil's import matrix (Petrobras 2015). Another expansion project, published in 2014, for the national refining park is the Abreu e Lima Refinery (Rnest), located in Pernambuco. Nowadays, the refinery's nominal capacity stands around 115 thousand bbl/d and, up until 2018, it will double, since the second refining set (Train 2) will be fully constructed (Petrobras 2015).

Nevertheless, to get to self-sufficiency on 2020, other two investments would be needed: Premium I and Premium II, located at Brazil's Northeast, with a total processing capacity of 600 thousand and 300 thousand bbl/d, respectively. These refineries, when concluded, will focus on the production of diesel, naphtha, aviation-fuel and liquefied petroleum gas, intending to fulfill the local demand (Petro and Química 2008).

In order to obtain an outlook of the Brazilian internal market, it is necessary to analyze the pre-salt production flow in comparison to the national refining potential.

2.1 Processing Capacity of Pre-salt Oil

To analyze the idle capacity of Brazil's refineries able to absorb the oil produced on pre-salt layers, the optimized utilization factor was set on 95% of the total processing capacity and, for refineries already operating, the share of capacity already in use was deducted from this value.

Many of the refineries owned by Petrobras have a high utilization factor. Thus, their absorption of oil coming from pre-salt layers would be low, adding up to a volume of 335 thousand bbl/d. One interesting refinery, with a negative idle capacity, is Lubnor (Lubrificantes e Derivados do Nordeste Refinery), which produces more than the recommended by ANP (95% of the total production capacity, keeping a margin for maintenance or emergency operations), and this overproduction occurs in one more refinery, Paulínia Refinery (Replan). Going through the private refineries, there is a bigger increase potential, in percentage terms, since they have a small capacity usage.

It is important to emphasize that four of the presented refineries are not currently in operation and, therefore, have a potential increase on 95% of its total capacity. These refineries are: Univen, closed since April 2014 due to financial problems; the Comperj and Premium I and II. Piling the idle capacity of the existing refineries, as seen above, with the capacity of the investments predicted, a total of around 1.5 million bbl/d can be added to the supply of petroleum derivatives on internal market through national refineries production. By then, we will have a refining nominal capacity of about 3.6 million bbl/d.

Based on this data, it is known the pre-salt volume to be refined internally, since there is a big expansion capacity to absorb it. However, not every refinery analyzed can receive this layer's oil as a raw material. The Map 1 shows the geographic location of the twenty presented refineries and the seaports closer to them, also distinguishing the refineries able to receive that type of oil and the ones that are not.

Three of the twenty refineries on the Brazilian refining park were excluded as potential receptors of this pre-salt extracted oil flow.

Revap, as debated before, is operating over the ideal capacity and cannot receive this additional oil. The Reman (Isaac Sabbá Refinery) has three problems regarding

Map 1 Geographic location of national refineries. *Source* Author's elaboration

the oil absorption: (a) it is located in the middle of the Amazon rainforest; (b) the oil transportation to its site would have an unjustifiable cost; (c) it is planned for high quality oil, different from the pre-salt one, which would require high adaptation costs. Also, Lubnor (Lubrificantes e Derivados do Nordeste Refinery) is incompatible with pre-salt oil, turning it into an unsustainable place for the shipment of this crude oil, since, besides operating with a high utilization factor (close to 100%); the refinery produces and exports high value-aggregated products. Adapting its foundation to the new oil would create an unprofitable situation.

Defined the hypothetic target of pre-salt production, it is important to discuss whether the amount of oil produced will reach up to national demand, both volumetric and, taking in account the refineries capacity, on derivatives.

3 Pre-salt Production and Internal Demand

In 2006 the volumetric self-sufficiency was disclosed, since national produced petroleum availability matched up to the consumption and the country's refining capacity to fill the Brazilian market demand (Petrobras 2005). However, governmental measures resulted in an increase on derivatives demand, leading to a huge shortfall regarding the available crude oil as well as the national derivatives production on the Brazilian trade balance. Nonetheless, this scenario could change in a close future. Chart 1 will show three scenarios for the petroleum supply and demand on Brazilian internal market: two of them predicted by OPEC, based on different tendencies, one optimistic (OPEC 2014) and one pessimistic (OPEC 2015), and another one displayed by Petrobras, with a conservative demand

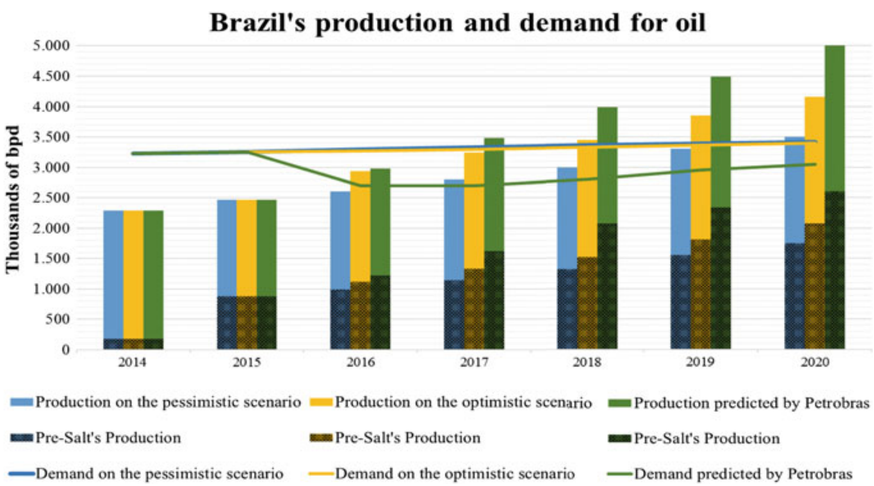

Chart 1 Brazil's production and demand for oil 2014–2020. *Sources* ANP (2016), OPEC (2015) and Petrobras (2014)

assumption and a bigger production, in its 2014 Business and Management Plan, on which the company predicts Brazil's self-sufficiency for the year of 2020. It must be accentuated that the data for the years of 2014 and 2015 comes from ANP 2016.

The most conservative demand scenario is the one used by Petrobras. Under that point of view, Brazil would reach volumetric self-sufficiency by 2016. On the optimistic data from OPEC, it would be reached by 2018. Yet, analyzing the pessimistic scenario of low economic growth, volumetric self-sufficiency would be fulfilled only in 2020. After justifying the volumetric kind above, we shall now proceed to the petroleum derivatives analysis on supply and demand.

4 Refineries Production and Internal Demand for Derivatives

Hereafter, the variables taken on account are: the production profile of each refinery operating with 95% of its nominal capacity, and the projections for internal demand (Petro and Química 2015). The chosen derivatives follow the importance that they represent on the Brazilian trade balance. To obtain the total refining park capacity, the predictions were assumed constant in percentage on the projects of each one of the refineries. Therefore, the second refining set (Train 2) of Abreu e Lima Refinery and Comperj will be fully operating on 2018. On the other hand, the Premium I and Premium II refineries are due to 2019, on its full capacity. The data can be analyzed on Chart 2 (a–f).

The demand published by Petrobras is more conservative than OPEC's and it is seen that, in comparison to the concluded ones for 2014 and 2015, this prediction

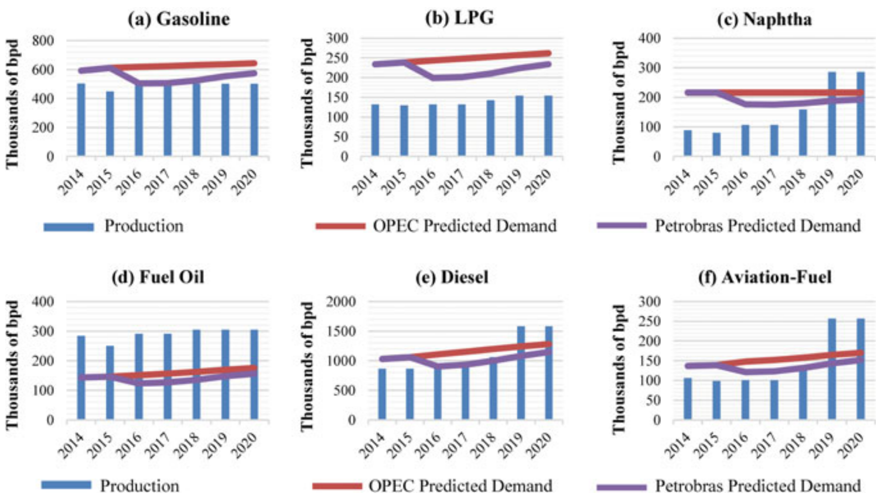

Chart 2 Refineries production and internal derivatives demand (2014–2020). *Sources* ANP (2016), Petro and Química (2015), OPEC (2015) and Petrobras (2014)

does not match reality. It is noticeable that the affirmation from Petrobras claiming that in 2020 we would be a self-sufficient country not only in volume but also in derivatives is founded on the thought that the demand would be lower than it actually was on the years following the prediction, 2014 and 2015. Also, even if the consumption was as Petrobras predicted, the self-sufficiency regarding all derivatives wouldn't be fulfilled simultaneously. In charts "a", "d" and "e" the consumption and supply matched up in 2016, maintaining this fact only through 2017 on the gasoline's case, with a constant demand growth that, although restrained, is not matched up by the production capacity on the commodity, even after Premium I and II are fully operating, since they are not planned to produce this derivative. In the other charts, "f" and "c", the self-sufficiency is reached only in 2019. Regarding the chart "b", based on liquefied petroleum gas (LPG), other variables such as the thermoelectric plants consumption and the production of ethanol would be necessary to analyze the real scenario concerning the derivative, which is not part of this article's scope.

Analyzing the prediction on demand made by OPEC in 2015, except for the LPG, it is clear that the shortfall regarding gasoline is very expressive, since the new investments were not focused on the production of this derivative. This strategic decision of Petrobras regarding gasoline can be related to other factors that were not taken into account in the analysis, such as: (a) the production of other kinds of fuel to fulfill Brazil's internal market; (b) renewable energy sources (biofuels and ethanol), on which the country is a huge producer; (c) the expressive weight of the other derivatives on the national import matrix.

5 Conclusion

Brazil has a significant oil production potential: with the volume from the pre-salt layer, the country will enter the small group of biggest producers of the commodity. However, in order to make the best out of this petroleum flow, it should be guided to national refineries, fulfilling the country's internal market demand and exporting petroleum derivatives supplied in excess, resulting in a higher value added transition than the mere crude oil exportation.

The internal demand also follows a growing trend. Even in the most conservative scenarios with low economic growth, the amount of petroleum derivatives demanded by the internal national market is not met by the national refining park, composed by the twenty refineries analyzed. The most acute shortcoming was on gasoline, which, surprisingly, does not participate in the investment plans of Petrobras.

At the hypothetic scenario considered in the analysis, on which every planned refinery would be working with a 95% utilization factor, the self-sufficiency is reached, in volumetric terms, by 2018, considering the projections of OPEC and Petrobras. However, the four big investments announced in 2014 (Rnest, Comperj, Premium I and Premium II) being totally operational are not enough so that the self-sufficiency in derivatives is reached, which evidences the urgent need of expansion of the national petroleum processing capacity to avoid the fate of countries like Venezuela, Mexico and Iran, huge crude oil exporters. Without new investments on the national refining sector, besides those planned in 2014, we forecast an increase on Brazil's trade balance deficit regarding petroleum derivatives.

The current outlook also exposes the possibility of a strong precariousness on the technologies involved in the national oil-refining sector. Therefore, the urge for new investments on the national refining sector, aiming the production of high value-added products, must be pointed out.

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Part V
Quality and Product Management

Relationship Between Operational Performance and Help Chain Critical Success Factors

Guilherme Tortorella and Diego Fettermann

Abstract One of the main pillars of Lean Manufacturing (LM) is the capacity to stop processes whenever problems are identified, correcting them before they move downstream; which is called *jidoka*. Within the concept of *jidoka*, one of the practices of control and elimination of waste is the help chain (HC). Few evidences have been found in the literature with regards to HC implementation, and the existent ones poorly describe how to operate, systematize and manage the HC in companies undergoing a LM implementation. In this paper we propose an instrument for assessing the relationships between the critical success factors (CSF) that promote HC, providing means to enhance operational efficiency and quality performance in companies undergoing LM implementation. The aforementioned relationships were determined and validated through a survey carried out with 50 Brazilian companies. Identifying relevant relationships between CSF and performance indicators may contribute to specify the context in which problems are expected to occur. Additionally, the study focuses on two contextual variables: (i) size of the company and (ii) time of lean implementation. Our results show that these size of the company and CSF have a significant relationship with quality. However, for efficiency, time of lean implementation seems to be significantly important to predict its performance.

Keywords Help chain · Critical success factors · Lean manufacturing · Operational performance

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1 Introduction

Lean Manufacturing (LM) structure is usually based on the Toyota Production System (Womack et al. 1992). LM practices aim to reduce waste and eliminate problems along the productive flow. One of the main pillars of LM system is the capacity to stop processes whenever problems are identified, correcting them before they move downstream; which is called *jidoka* (Baudin 2007). Within the concept of *jidoka*, one of the practices of control and elimination of waste is the help chain (HC) (Melo and Rodrigues 2011). The HC is an interaction and involvement routine applied among many levels of the organization in order to rapidly solve problems whenever they emerge, re-establishing the productive flow (Kamada 2008). The HC allows the creation of a methodology for identification, registration and resolution of problems, turning the sense of urgency and discipline as a daily practice within the organization (Liker and Meier 2007).

Since it is part of a broader cultural change, the involvement and commitment of intermediate leaders and senior managers are fundamental for HC's efficacy (Módolo and Moretti 2011). The HC demands zero tolerance to problems that generate waste, establishing an environment where it is not about who made the mistake, but what the problem is. This mental model is reinforced in LM implementation (Pollon 2013). Thus, companies must identify the proper skills and competencies in order to train and enable leaders and employees to accordingly perform in this scenario (Tracey and Flinchbaugh 2006). Despite the importance of the subject, few evidences have been found in the literature with regards to HC implementation (Flinchbaugh 2007). Further, the existing references poorly describe how to operate, systematize and manage the HC in companies undergoing a LM implementation (Melo and Rodrigues 2011). In this paper we propose an instrument for assessing and understanding the relationships between the critical success factors (CSF) that promote HC, providing means to enhance operational efficiency and quality performance in companies undergoing LM implementation. The aforementioned relationships were determined and validated through a survey carried out with 50 Brazilian companies. We thus provide an empirically validated instrument for assessing HC critical success factors and their impact on key operational performance indicators with no parallel in the existing literature. Quality (scrap and rework) and OEE (overall equipment efficiency) were chosen as performance indicators due to their recognized relevance in previous researches related to HC approach (Smalley 2005; Wong et al. 2009).

2 Help Chain and Critical Success Factors

The starting point in a HC is the problem identification and definition. A specific problem may need a specific HC, generating the need for diversified HC (Maganhoto 2012). In a shop floor environment, most problems are related to quality, machine setup or stoppage, safety/ergonomics, absenteeism or delays (Pollon 2013). The first intervention is, generally, done by the operator or the person who is closest to the point of cause. Thus, operators must have proper training and skills in order to know what and how to solve problems. Moreover, the scope of problems that they can act must be specified, so that they know when to ask for help (Spear 2009). According to Andrade (2001), there are eight main steps that must be accomplished for implementing a HC: establish objectives, define pilot area, define HC rules, define frontline leaders and involved hierarchy levels, train leaders, test pilot, check results and correct problems, and replicate to other areas.

The identification of the CSF allows the measurement of the essential characteristics that enable a systematic HC implementation (Jusko 2010). Therefore, there are a few pre-requisites that organizations may need to fulfill in order to successfully implement a HC process (Dettmer 2011). One of these pre-requisites includes proper training and technical knowledge for each supporting level of the HC. This is an important factor, since it provides agility and efficacy to HC (Pollon 2013). Furthermore, frontline leaders must be able to teach and develop their employees in order to disseminate such knowledge. Keil et al. (2007) comment that, curiously, most problem solving and escalation research has focused on the behavior itself, rather than trying to build a causal model to explain why the behavior occurs. Table 1 presents the frequency of appearance of the most cited HC critical success factors in literature. Nine factors were mainly reported in the investigated researches. From these, "support of other areas" emerged in most references. This factor comprises the relationship level that functional areas, such as engineering, maintenance and quality, present with the actual problems on the shop floor (Prabhushankar et al. 2015). On the other hand, "sense of urgency" was the least cited factor among the nine ones. The establishment of the "sense of urgency" allows the achievement of results by immediately carrying out tasks delegated by the leadership (Sobek II and Smaley 2011).

Table 1 Appearance in literature of HC critical success factors

CSF	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Communication			X	X		X	X	X	X	
Training	X		X		X		X			X
Discipline			X		X	X		X	X	X
Sense of urgency		X	X	X				X		
Support of other areas	X	X	X	X	X		X	X		X
Knowledge and focus on the flow	X	X	X	X		X		X	X	
Quality tools application	X	X	X					X	X	
Follow up routine and analysis	X		X	X	X	X				X
Leadership			X	X	X				X	X

Authors: (1) Liker and Meier (2007); (2) Flinchbaugh (2007); (3) Duque and Cadavid (2007); (4) Baudin (2007); (5) Kamada (2008); (6) Pinto (2010); (7) Liu et al. (2010); (8) Alvarez and Perry (2015); (9) Jasti and Kodali (2015); (10) Prabhushankar et al. (2015)

3 Research Methodology

There are three stages to the research method proposed here: (i) questionnaire development and data collection, (ii) CSF consolidation and (iii) regression models. For the first stage, we used the following criteria to select companies and respondents: implementing LM and geographically located in the south of Brazil, in order to control the effect of environmental factors, such as availability of skilled labor. Questionnaires were sent by e-mail to former students of executive education courses on lean offered by a large Brazilian University since 2008. The same database of respondents was used in previous studies (e.g. Marodin and Saurin 2015; Tortorella et al. 2015).

The final sample was comprised of 50 valid responses. Most respondents were from large companies (51%); the majority of companies belonged to the metal-mechanical segment (25%); the average experience time of LM implementation was 4.2 years on shop floor activities. Regarding the job title, there was a predominance of manufacturing or continuous improvement engineers (54%). The questionnaire had three parts. The first part aimed at assessing the level of impact over the operational performance indicators (dependent variables). A 5-point scale ranging from 1 (low performance) to 5 (high performance) was used in the questionnaire. Further, demographic information of respondents and their companies was asked in the questionnaire in order to characterize the sample. The second part of the questionnaire intended to identify the levels of the control variables: (i) number of employees (size) and (ii) time of LM implementation. For the first variable, previous studies indicated that this factor can influence the use of LM practices (Shah and Ward 2003). To evaluate size, we included a dummy variable (0 = small; 1 = large). The second variable "time of LM implementation" in the company was also considered in the study; since most experienced companies are often more mature in lean practices implementation (e.g. Scherrer-Rathje et al. 2009). The third part comprised 9 questions aimed at measuring the degree of adoption of the nine CSF. In order to assess such degree of adoption for the independent variables, we developed a questionnaire using a five-point Likert scale (1 = low implementation to 5 = high implementation). We tested for non-response bias as proposed by Armstrong and Overton's (1977) using Levene's test for equality of variances and a *t*-test for the equality of means between early and late respondents. Results indicated no differences in means and variation in the two groups, with 95% significance. Finally a reliability assessment of the questionnaire was performed determining the Cronbach's alpha values. CSF displayed high reliability, with alpha value of 0.867. In order to consolidate the assessment of the nine CSF, we propose an overall score for each one of companies that answered the questionnaire. The implementation level for each factor denoted by c_j ($j = 1, \ldots, 9$) was weighted by its theoretical level of importance w_j, whose values are based on the outcomes provided by Maganhoto's (2012) research. In his study, eight experts were interviewed, with an average experience of thirteen years in LM implementation, and asked them to indicate in a pairwise comparison which factors were more important for the HC implementation. The total points attributed by the experts allowed the establishment of an importance weight for each factor, represented by the vector **w**. Therefore, the overall score for each company i (i = 1, …, 50) is given by csf_i using the following expression:

$$csf_i = \sum c_j \times w_j, \quad j = 1, \ldots, 9 \tag{1}$$

Regarding the regression analysis, Ordinary Last Squared (OLS) regression analysis method was used to describe how the CSF are associated with the quality and OEE performance indicators. A regression was performed in two stages. In the first stage it was included only the control variables, while the second stage comprised the independent variable csf_i. Both stages were applied to identify the association between CSF and the operational performance indicators (dependent variables). The calculation of the regression coefficients requires that all quantitative predicting variables (control and independent variables) are not correlated (Tabachnick and Fidell 2001). The high bi-variate correlations between some of the predicting variables suggest multicollinearity, which might be a problem for regression analysis (Hair et al. 2006). Therefore, to evaluate the presence of multicollinearity between the control variable "time of LM implementation" and the independent variables csf_i, it was used the Pearson's correlation analysis. Results indicate no significant correlation between them ($\rho = 0.159$; p-value = 0.310). Further, the variance inflation factor (VIF) was calculated, which confirmed no significant multicollinearity (VIF < 10) for all stages of regression analysis. OLS models were tested for normality, linearity, and homoscedasticity (Hair et al. 2006). We examined the models' residuals to check for normality; linearity was tested with partial regression plots for each CSF; homoscedasticity was visually evaluated plotting standardized residuals against predicted values. Models satisfied all assumptions.

4 Results

Regarding the sample initial results, Table 2 brings the questionnaire's average, importance weight, standard deviation and minimum and maximum values for each CSF and operational performance indicators. All CSF are partially implemented in the studied companies, and quality performance appears to lower than OEE performance. Considering quality performance prediction, the first stage of OLS regression indicates that the regression model with control variables presents a significant positive effect (p-value < 0.01). The second stage of OLS regression, which includes the variable cfs_i, also shows a significant positive effect to predict quality performance indicator. Further, the inclusion of csf_i provides a significant increase (p-value = 0.014) of prediction capacity of quality performance. Overall, the regression model in the second stage presents an R-square adjusted of 0.365.

Table 2 Descriptive results of the questionnaire application

CSF	Importance weight	Average	Std. dev.	Min	Max
1- Communication	12	3.15	1.26	1	5
2- Training	27	3.37	1.14	1	5
3- Discipline	48	3.26	1.00	1	5
4- Sense of urgency	37	3.32	1.15	1	5
5- Support of other areas	35	3.26	1.25	1	5
6- Knowledge and focus on the flow	18	3.30	1.15	1	5
7- Quality tools application	23	3.18	1.12	1	5
8- Follow up routine and analysis	32	3.33	1.10	1	5
9- Leadership	55	3.32	1.15	1	5
Quality (1–5 likert scale)		2.86	1.14	1	5
OEE (1–5 likert scale)		3.34	1.28	1	5

Thus, it is possible to mention that the implementation of CSF have a significant effect to improve quality performance in the studied companies. Regarding the obtained coefficients from the OLS regression in the second stage, "size" has a significant effect in quality performance ($\beta = 0.896$; p-value = 0.002). This finding indicates that quality performance is more likely to be higher in larger companies. On the other hand, the effect of "time of LM implementation" does not seem to be significant (p-value = 0.526) to predict quality performance. Despite the significant contribution of csf_i to predict quality performance (p-value = 0.014), its coefficient ($\beta = 0.313$) is smaller than "size".

In the OLS regression to predict OEE performance, the first stage indicates that control variables have a significant positive association (p-value = 0.011). However, the second stage of OLS regression shows that the inclusion of the csf_i may not improve the regression model capacity to predict OEE performance (p-value = 0.321). This fact denotes that higher levels of CSF implementation are not likely to provide an improvement in OEE performance. Overall, the control variables can explain only 16.2% of OEE performance, which suggests that, for the studied companies, there may be other variables not included in the model that can explain its performance. Further, only the coefficient for "time of LM implementation" has a significant contribution to predict OEE (p-value = 0.001). The variables "size" and csf_i seem to be not significant to OEE prediction (p-value = 0.893 and p-value = 0.0.321, respectively). Our results indicate that differences in companies' size and CSF implementation level are not likely to significantly affect OEE performance.

5 Conclusion

This research presents some important theoretical contributions to the state-of-the-art on LM implementation. We propose a new approach to identify whether help chain critical success factors (CSF) contribute to the improvement of the operational performance (OEE and quality). Our approach identifies the association level between CSF for HC and operational performance, focusing on specific characteristics of the organization in which they will be implemented. Using our proposition, researchers may choose the context and CSF with the highest likelihood of improving quality and OEE performance in the company under analysis. A set of 9 different CSF that represent the operational space surrounding HC implementation were identified and grouped into 1 main index, contributing to establish an operational complement to the conceptual definition of HC. We also provide a deeper understanding on how these CSF can support operational performance improvements, allowing companies undergoing lean implementation to better manage their lean implementation. We argue that, viewed individually, CSF may not significantly benefit the key performance indicators involved in manufacturing processes, but together, grouped as an index, they are likely to influence these indicators. Moreover, some results demonstrate that the association between CSF and operational performance may not be as suggested in the existing literature. Regarding the proposed objective, this investigation empirically validated the association between HC critical success factors and operational performance indicators (OEE and quality). Due to poor evidence in literature on the likelihood of any interdependent influence, further investigation would add more information and help to establish a holistic perspective about the problem, identifying interactions between CSF and their influence on operational performance.

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An Alternative Test of Normality for Improving SPC in a Portuguese Automotive SME

Radu Godina, Eduardo M.G. Rodrigues and João C.O. Matias

Abstract In the context of a worldwide market competition, the current economic framework defies organizations with numerous challenges. Nowadays is no longer enough to produce. The modern production values are based on quality as a condition for achieving productivity and competitiveness. However, quality is not static, it is constantly being changed, and since customers are increasingly demanding, any industrial organization that aims to be competitive it is compelled to innovate. In such competitive environment the organizations increasingly seek to produce with the best quality at the lowest possible cost, to ensure their own survival. One tool to achieve the aforementioned targets is the Statistical Process Control (SPC)—a powerful management method which allows for both quality improvement and waste elimination. In this paper a case study of a Portuguese automotive small and medium-sized enterprise (SME) where SPC is implemented is analysed. The normality test used at the SME in question is Kolmogorov-Smirnov (K-S). In this case the SPC method shows that the process is centred and meets the acceptance criteria and the K-S shows that the recorded data follow a normal distribution. However, when the K-S test is replaced by the Shapiro-Wilk test the results show that the tested data are not from a normally distributed population. In this paper the results and the consequences of the Shapiro-Wilk test are analysed and discussed and a solution is proposed to improve the utilized SPC tool at the SME.

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Keywords Statistical process control · Shapiro-Wilk test · Kolmogorov-Smirnov test · Quality improvement · Automotive industry

1 Introduction

The control and quality improvement has become one of the core strategies of business for countless organizations, fabricants, distributors, transporters, financial, health and state service organizations (Oakland 2008). Quality is a competitive advantage and any given organization that satisfies its clients through quality improvement and control can prevail over the competition (Schröder et al. 2015).

The increasing globalization and the increment of automatized production capacity stimulate the competitiveness of automotive plants (Kato et al. 2016). For the automotive industry the quality is expressed through the customers' satisfaction regarding to the products and offered services (Sanches et al. 2008). An answer to this increasing demand is the Statistical Process Control (SPC)—a set of tools for process management and for determination and monitoring of the quality of an organization outputs (Khorshidi et al. 2016). Even though the occurrence of defects is almost always inevitable due to the production mechanisms in operation (Plumlee and Shi 2013) the SPC could be used to reduce the appearance of defective pieces. SPC is also a strategy for improving capability through the reduction of variability of products, deliveries, processes, materials, attitudes and equipment (Oakland 2008). The correct implementation and use of the SPC can lead to decisions based on facts, to a growing perception about quality at all levels, to a systematic methodology concerning problem resolution, to a gathering of experience and to all kind of improvement, even in communication. Predominantly in manufacturing and concerning quality, SPC is the most widely used technique (Cook et at. 2006) and once properly applied it can bring operational and financial benefits (Rungtusanatham 2001).

Control charts are used to check for process stability (Teyarachakul et al. 2007). In this context, a process is said to be "in statistical control" if the probability distribution representing the quality characteristic is constant over time. If there is some change over time in this distribution, the process is said to be "out of control." (Joekes and Barbosa 2013). In contrast, an out of control condition signals the presence of assignable or special cause variation of the distribution (Woodall 2000). This type of variation has to be identified and eliminated in order to be able to return the process to a state of statistical control (Cook et al. 2006).

Variable control charts are intended to control process or product parameters which are measured on a continuous measurement scale such as pounds, inches, miles, etc. rather than defective quantity (Anjard 1995). For a manufacturing process, the most common control charts in use are mean and variance that must be monitored together to ensure high quality. Shewhart $\overline{X}$ and R control charts have been simultaneously used to control the process mean and variance for more than half a century (Lee 2013).

Process capability analysis has become in last two decades a significant and well-defined tool in applications of SPC to a continuous improvement of quality and productivity (Wu et al. 2009). Thus, the ability of the process to meet specifications is assessed through calculation of one or more capability indices (Stuart et al. 1996).

This paper aims to contribute to solve a quality problem, particularly the improvement of a process quality using statistical tools. In this paper a case study of a Portuguese automotive SME where SPC is implemented is analysed. The normality test used at the SME in question is K-S. In this case the SPC method shows that the process is centred and meets the acceptance criteria and the K-S shows that the recorded data follow a normal distribution. However, when the K-S test is replaced by the Shapiro-Wilk test the results show that the tested data are not from a normally distributed population. In this paper the results and the consequences of the Shapiro-Wilk test are analysed and discussed. Finally, a solution is proposed to improve the SPC tool in use at the SME.

This paper is organized as follows. In Sect. 2 is presented the description of the intended industrial unit and the analysis of the process, data collection and utilized control charts. In Sect. 3 the Shapiro-Wilk test is briefly discussed and in Sect. 4 an analysis of the obtained results and their discussion is made. The paper concludes in Sect. 5 with general conclusions and recommendations.

2 The Industrial Unit and the Process

The case study comprises one automotive supplier enterprise, mainly, one factory unit. Since the main objective of this research is to demonstrate how the SPC can assist not only in quality control but also in management decision making an appropriate case study from a Portuguese automotive SME was used. The organization operates in two shifts of 8 h each per day. It supplies the main Original Equipment Manufacturer (OEM) of the sector with stamped metallic pieces, subassemblies, welded assemblies, chassis and more recently, with a few precision pieces. The factory is characterized by different processes of fabrication, like manual and automatic welding of structures or small components, surface treatment and a wide range of different dimensions stamping. The production process of each product follows a specific flow, since each stamped piece requires a specific tool.

For such processes and in order to have a higher quality control at various stages the SME has implemented a wide range of SPC tools. During the production process of metallic pieces the SPC is required by the customer specifications as a mandatory tool.

The collection frequency of data for measurement and inspection is established on a sample of 5 pieces per shift. The dimension measurement is effectuated by a

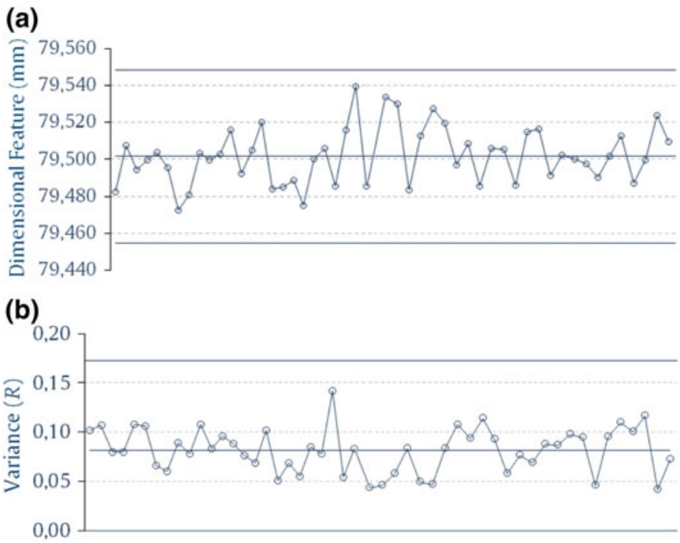

Fig. 1 Variables control chart of 50 samples of **a** mean and **b** variance

coordinate measuring machine (CMM). For studying the dimensional feature of the manufactured piece a control chart ($\overline{X}$, R) is used. As target the dimensional feature of 79.5 mm with a superior and inferior tolerance of 0.15 mm is established. In Fig. 1 can be observed the results after 50 the collection and measurement of 50 samples.

The normal probability plot is a graphical method to identify substantive departures from normality and the K–S test is a nonparametric test of the equality of continuous, one-dimensional probability distributions that can be utilized to compare a sample with a reference probability distribution. The normal probability plot and the K-S test associated to the SPC control chart existent at the industrial facility show that the analysed data follows a normal distribution as can be seen in Figs. 2 and 3.

Especially, in Fig. 3 can be noticed that the observed cumulative frequency closely fallows the expected value of normal distribution.

Other interpretation of control charts can made through the study of the occurrence (or not) of non-random patterns. In process improvement efforts, the Process Capability Index (C_{pk}) is a statistical measure of process capability and is defined by the ability of a process to produce output within specification limits. The non-random patterns and C_{pk} and other process capability ratios are presented in Table 1.

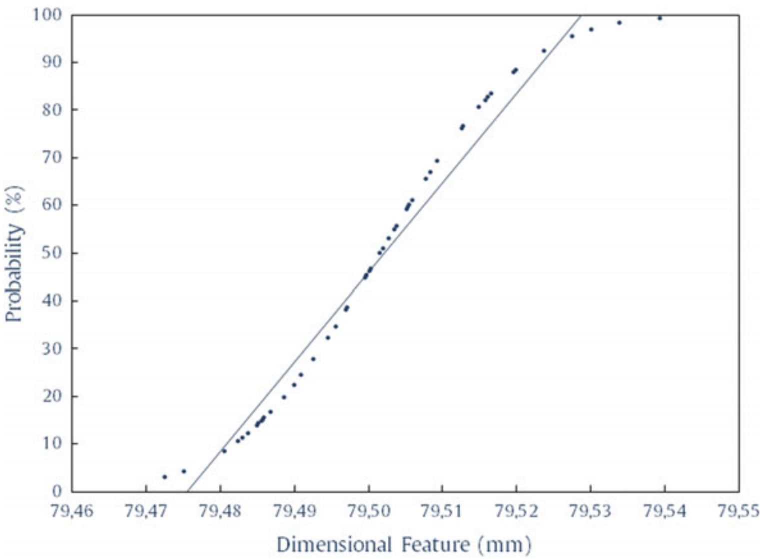

Fig. 2 The normal probability plot

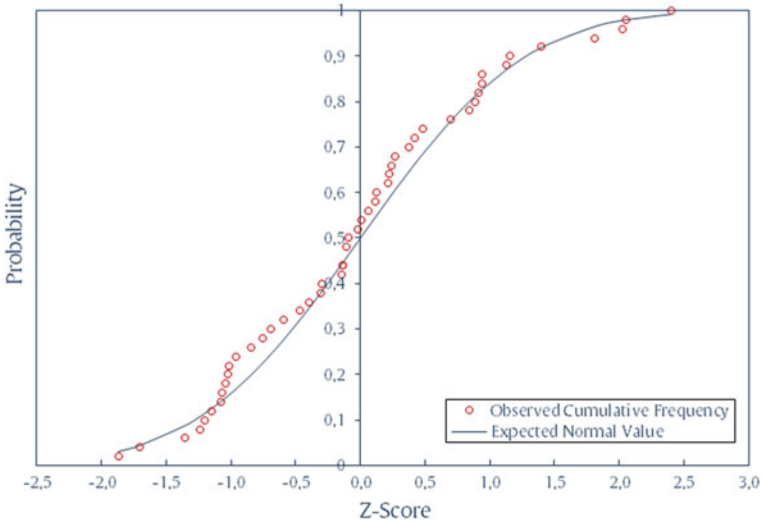

Fig. 3 The Kolmogorov–Smirnov test

Table 1 C_{pk} and other process capability ratios

Number of readings	250
Lower spec limit (*LSL*)	79.350
Nominal	79.500
Upper spec limit (*USL*)	79.650
Out of control limits	0
Average range (*R*)	0.08
Upper capability index (C_{pu})	1.41
Lower capability index (C_{pl})	1.41
Capability index (C_p)	1.41
Process capability index (C_{pk})	1.41

3 Shapiro-Wilk Test

The Shapiro-Wilk test uses the null hypothesis principle to verify whether the aforementioned sample $b_1, \ldots, b_n$ is originated from a normally distributed population or not. Therefore, if the *p*-value is greater than 0.05, then the null hypothesis is not rejected and consequently there is evidence that the tested data comes from a normally distributed population. The Shapiro–Wilk statistic *SW* is based on the ratio of two estimates of scale (Kim 2011) and is expressed by:

$$SW = \frac{\left(\sum_{i=1}^{n} a_i b_{(i)}\right)^2}{\sum_{i=1}^{n} \left(b_i - \bar{b}\right)^2} \tag{3.1}$$

where $b_1, \ldots, b_n$ is a sample of continuous distribution and $b_{(1)}, \ldots, b_{(n)}$ is the order statistics of $b_1, \ldots, b_n$, a_i is a constant and where $b_{(i)}$ represents the *i*th order statistic, i.e., the *i*th smallest number in the sample. The sample mean $\bar{b}$ is expressed by:

$$\bar{b} = \frac{(b_1 + \ldots + b_n)}{n} \tag{3.2}$$

The constant a_i is represented by:

$$a_i = (a_1, \ldots, a_n) = \frac{m^{\mathrm{T}} V^{-1}}{\left(m^{\mathrm{T}} V^{-1} V^{-1} m\right)^{1/2}} \tag{3.3}$$

where:

$$m_i = (m_1, \ldots, m_n)^{\mathrm{T}} \tag{3.4}$$

where $m_1, \ldots, m_n$ are the expected values of the order statistics of independent and identically distributed random variables tested from the standard normal distribution and V represents the covariance matrix of the aforementioned statistic order.

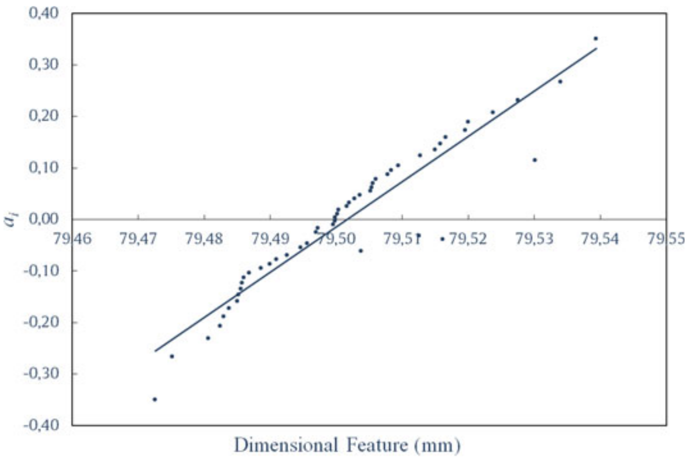

Fig. 4 The Shapiro–Wilk test

4 Result Analysis

The recommended minimum C_{pk} for two-sided specifications is 1.33 (Pan et al. 2016) and the results shown in Table 1 show that this criterion is correctly followed. Also, all the results from Figs. 1, 2 and 3 show that the process is capable. However, since *p*-value is defined as the probability of obtaining a result equal to or "more extreme" than what was actually observed, when the same samples are analysed through a Shapiro–Wilk statistical test, the *p*-value is 0.023 which is <0.05, thus the hypothesis that the data comes from a normally distributed population is rejected as can be observed in Fig. 4.

In literature is stipulated that among many normality tests put to comparison, the Shapiro-Wilk test is the most powerful test for all types of distribution and sample sizes while K-S test is the least one (Razali and Wah 2011). The management of the industrial facility analysed the results obtained through the Shapiro-Wilk test. A conclusion after employing an Eight Disciplines Problem Solving (*8D*) method was reached. First, one ($\overline{X}$, R) chart should be used for each shift and not one for both since each working shift is inherently different. Second, the K-S test was considered obsolete and in the control chart used at the factory it was replaced by the Shapiro-Wilk test.

5 Conclusion

In this paper a case study of a Portuguese automotive SME where the SPC tool is implemented was analysed. The normality test used at the SME in question is K-S. In this case the SPC method shows that the process is centred and meets the acceptance criteria and the K-S shows that the recorded data follow a normal distribution. However, when the K-S test was replaced by the Shapiro-Wilk test the results showed that the tested data were not from a normally distributed population. The obtained results through the Shapiro-Wilk test were analysed and a conclusion after employing an *8D* method was reached. In light of the recent discovered non-conformity two solutions are proposed to improve the utilized SPC tool at the studied SME. It was decided that each shift should use its own chart and the K-S test was replaced by the Shapiro-Wilk test in the standardized SPC tool used at the factory.

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Part VI
Knowledge and Project Management

Definition of a Project Performance Indicators Model: Contribution of Collaborative Engineering Practices on Project Management

Marcelo Silva Pereira and Rui M. Lima

Abstract Monitoring and controlling the progress of project activities are important processes for managers, because allow them identify the limits which may compromise the project progress, comparing the current situation with elaborate planning and consequently assisting the managers to balance the project activities and put them according to the initial plan. To support the needs of project monitoring and controlling, the PMI—Project Management Institute—indicates a process set described on the PMBok—Project Management Body of Knowledge—which assists the project managers during their activities. Not all activities described in the PMBoK relates in a collaborative way all the involved in a project (collaborators, stakeholders, providers). Considering the need for collaboration, this work intends to contribute to answer to the following questions: how to create conditions to collaboration among the involved in projects through of project management? What techniques and tools can be used to create conditions of collaborative engineering inside of projects? Therefore, in this paper tools and techniques for monitoring and controlling of project management practices are compared with collaborative engineering practices based on systematic literature review. Furthermore, supported by this comparison a project performance indicators model approach for monitoring and controlling of project performance is presented.

Keywords Project management · Project monitoring · Project control · Collaborative engineering · Performance indicators · Tools and management techniques

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1 Introduction

A project is a system that during its development can lose the balance, deviating from its established initial objectives, requiring a correction plan. As soon as this deviation is identified the better for the system. Therefore, performance indicators may be established with the objective of discovering, as soon as possible, imbalance situations and provide timely information to develop action plans to recover the project balance (Miguel 2010). Still according with Miguel (2010) and Kerzner (2011), there is a plenty of reports and tools of numeric, tabular and graphic forms for project control, whose goal is showing the real situation of the project in relation to the respective plan. These tools are built to support the control activities, highlighting aspects and issues of the project, such as real situation versus plan, among others characteristics.

During decades, it was believed that the unique information who needed to be sent to customers and stakeholders of the projects were basically associated to cost, time and ambit referring to triangle of the constraints (Kerzne 2011) or cost, time and quality referring to iron triangle (Atkinson 1999). Even so, monitoring the project progress to be beyond of projects time and cost, other areas can have more importance according to its complexity. Therefore, identifying and using methods that assist the diagnostic of atypical conditions in project performance is a critical activity for the project success. Nevertheless, the monitoring and control processes should not consider only time and cost, but also the inconsistent issues and behaviors that can be identified during the execution of project activities (Eckerson 2006) in different knowledge areas, such as Project Value, Quality, or Image/Reputation (Kerzner 2011).

For Petersen & Wohlin (2009), the processes of project management practice indicated by PMI, can be used to measure and improve the project development and may be used as starting points to identify eventual problems and to find the process improvements in the long term. However, considering the diversity of knowledge areas, tools and techniques to be monitored by managers, it is necessary to create conditions to engage stakeholders in project monitoring, from the definition of performance indicators, through decision making processes. The objective of this paper is the identification, based on literature review, of tools and common techniques that are used both on the monitoring and control process group of the PMBOK and on the collaborative engineering practices, with a special focus on the ones that collaboratively involves the project stakeholders. This will act as a starting point for providing the collaborative environment for performance indicator management.

2 Project Management and Collaborative Engineering Practices

The PMI-PMBOK (2013) aggregate the project management processes in ten different knowledge areas. Each knowledge area represents a complete set of concepts, terms and activities that compose a professional field of projects management or specialization. For each knowledge area, the PMI-PMBOK (2013) presents processes to monitor and control the project management, however, it is only possible to accomplish the monitoring and controlling of the project progress together with the activities of the execution process, because both groups are completely interconnected.

During project execution, the managers need to use approaches to monitor its development (PMI-PMBOK 2013). Even that managers can use knowledge about the tools and techniques referred for each development phase, it is still necessary to define parameters and identify values to measure the performance of the respective knowledge areas. In this way, managers, teams and customers will be able to monitor and control the project progress and accomplish changes if it is needed.

Aiming to create conditions for promotion of project management based on project indicators, Cooke-Davies (2002) emphasizes two important aspects that shall be verified during the project execution: (a) measure the developed artifacts during the project, related to the general goals initially established; (b) measure the utilization of resources of the project in relation to cost, time and quality, among others project keys areas.

Using methodologies to improve processes, such as Lean and Agile, can contribute to increase the efficiency on project development, resulting in additional visual tools to monitor the progress of the activities, reduction of activities that not add value to project results, and assist on the definition of integrated performance key indicators (Wang, Conboy, & Cawley 2012). However, the need of assisting project development teams to make decisions and execute actions requires the integration of several knowledge areas. In order to lead effectively with this need, multidisciplinary teams (managers, technicians, customers, collaborators, and so on) using collaborative engineering practices can help to improve the expected results and reduce the complete lifecycle project (Alting, M., Boelskifte, Clausen, & Jørgensen 2006).

Collaboration can be described as the process in which multiple interdependent people work together to achieve a higher goal that would not be possible for an individual to achieve alone (Todd 1992). The collaborative engineering focuses on creating conditions to improve the efficiency of teams and for organizations to execute collaborative actions (Lu, Elmaraghy, Schuh, & Wilhelm 2007).

There are a few tools and techniques that are indicated both for the practice of collaborative engineering and project management. These practices create conditions for greater collaboration and involvement of the projects stakeholders.

An example of practice of collaborative engineering is the use of collaborative tools (e.g. CSCW, visual collaborative tools) during the development of projects, with the goal of supporting the interactions between the involved stakeholders on developing activities of product/service design (Daft & Lengel 1986). The use of multidisciplinary teams applying concepts of collaborative engineering can contribute to have more interactions between the participants of the project during its development.

Monteiro (2004) presents some techniques and tools used in the collaborative engineering knowledge area: brainstorming techniques; nominal group and Delphi; support system of make decision; communication tools; meeting support tools; performance evaluation and workflow systems.

Therefore, it is combination of practices specified by the project management processes, aligned with the collaborative engineering practices that will support the proposal of a performance indicator model. This model is targeted at the direct collaborators of the project with the aim of creating new parameters for performance evaluation during the project development phase.

3 The Performance Indicators Model

One of the main obstacles faced by project teams when evaluating the activities performance, in order to make decisions and to execute correction actions, is the lack of information. As an example, it is possible to refer the difficulty to get information about project performance, lack of information to be sent to customers, and failure to deliver the results until the due date. It can also be mentioned the lack of participation and integration of the team members, the attribution of tasks to the wrong person, the inability of distinguish between facts and opinions, a predisposition to an individual solution, several and long meetings and the lack of communication between the involved in the project (Drury, Conboy, & Power 2012).

In this context, a performance indicators model based on collaborative engineering can assist the team to define them own performance key indicators to the projects that will support the monitoring processes during the project phases. This model will allow to provide information to take corrective decisions if some issue of the project is not according to the established plan. Besides that, it allows a qualitative analysis of progress through quantitative data. The performance indicators model of project progress proposes procedures that may to be used for its application in each stage of project development. Figure 1 shows the interaction of phases between the collaborative engineering practices (definition of performance indicator, accompaniment of indicator by the team, analysis of the indicator and evaluation of indicator) and the project development cycle (planning, execution, review and retrospective).

It is important to understand how work a performance measurement process and how build indicators to assist the teams during the project execution, then, no one better than the own team to define them. For Harbour (2009), a performance measurement process shall provide the answer for tree basic questions: Why measure? What measure? How measure? Highlighting that the answer to the two

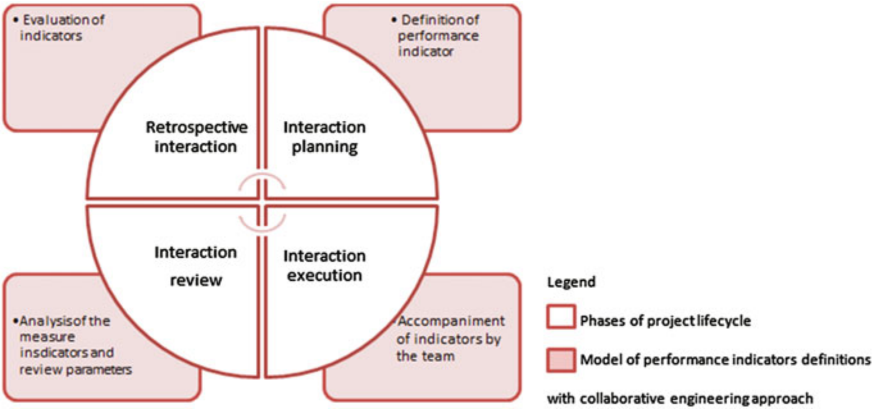

Fig. 1 Interaction of the indicators definition model with the project development phases. Adapted from Drury, Conboy, & Power (2012)

last questions are dependents of the answer obtained on the first. It can be added to this measure process the question "When measure?", because the moment to collect the information is an important parameter to calculate the response time.

The first stage of the performance indicators definition model inside of the project development cycle is the "definition of the performance indicators". In this phase, the team, gathered after defining the cycle goals, establishes indicators for each knowledge area that judge to be important to success of project (it is not mandatory for all areas, as well as there is not a limited number of indicators by area). In addition to create the indicators, the team defines the parameters that must or not be achieved during the project execution, according to them experience and/or difficulties that can occur. For example: Indicator to measure the number of failures detected by the quality area: the team can have a maximum of 10 failure by cycle; Indicator to measure the number of meeting with costumers to provide and receive feedbacks: the team can have a minimum of 2 meetings with customer by cycle.

The second stage of the model is the "monitoring the indicators by the team". This phase consists of updating and monitoring the established indicators by the team during the development activities of project. This monitoring can be done using communication tools, executing daily meeting or others alternatives established by the team. The third stage is the "Analysis of the indicators data measured and parameters redefinition". This phase consists of doing an analysis between the established values as parameters and the real values achieved, checking the negative and positive impacts inside of the project. The redefinition parameters consist of evaluating if the objectives defined still are reachable. The last stage "Indicators evaluation" consists of evaluating the indicators by the team, checking if the same contributed or not to improve the team performance.

The model goal is to challenge the team to overcome its performance and to commit the members with the established goals, and to offer a tool to analysis the

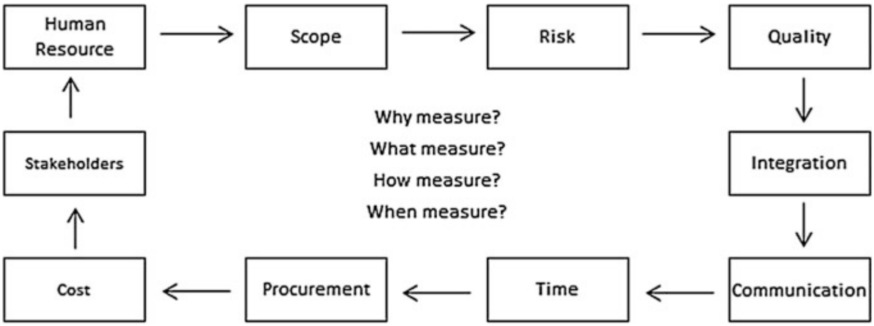

Fig. 2 Cycle of activities of the performance indicator definition model

procedures executed. This way, the team identifies the points to be improved and discusses solutions in a collaborative way. The Fig. 2 shows the cycle of activities, by knowledge area, of the performance indicator definition model. This cycle of activities can be used by the team to build and evaluate their indicators.

The division of the project management in knowledge areas facilitates the process of identification of measurable issues about the project progress, the monitoring of the activities through the performance indicators and assists to take decisions to execute actions for improvement of their procedures.

The Fig. 3 shows tools and techniques used on collaborative engineering practices and on monitoring and control process of the project management indicated by PMI-PMBOK (2013) highlighting in the central part of the picture, commons tools and techniques between the two approaches. It is important to highlight that tools and techniques of collaborative engineering, connected by dotted lines, are used by other knowledge areas in the project management practices involving stakeholders (managers, collaborators, providers and communication).

Other important point to observe is that the commons tools and techniques between the project management practices and collaborative engineering do not integrate only the knowledge areas connected to the development process (time, cost and quality), but cover with more emphasis the project stakeholders, direct or indirectly, facilitating the application of performance indicators definition model using the collaborative engineering practices.

The fact that collaborative engineering approach aims involving all stakeholders in the project development phases, has as main goal to achieve the project success, to satisfy the customers and to get success in the project management (Cooke-Davies 2002). However, according to Cooke-Davies (2002), other advantages are related with collaborative engineering approaches, higher success in research projects, differential of the teams as marketing strategic, financial improvement and organizational success.

Fig. 3 Collaborative engineering tools and techniques used in project management

4 Conclusion

The need of monitoring and controlling the performance indicators in a project is a trend that will require not only management skills, but also the effort of all involved in the project (collaborators, customers, providers among others), because the development of a project currently consists in a set of activities that go beyond the limits of companies. Thus, defining performance key indicators, monitoring them during the execution, evaluating the results during the project life cycle, allows the team to collaboratively take decisions and execute improvement actions.

For this reason, it is important developing and evolving techniques and tools that assist the managers and the other stakeholders of the projects to improve them process and to increase them performance of collaborative way in of management practices to find the project management success and consequently satisfying the requirement of clients.

The model proposed in this work was based on theoretical research, suggests a solution to fill in the need to increase the involvement between collaborators, managers, providers and clients inside the project development activities, and create conditions to a higher interaction between the stakeholders. Using a performance indicator definition model aligned with the collaborative engineering practices, increase the chances to establish a consistent monitoring system covering all project stakeholders. The following steps will be centered in evaluation of this model with real software development teams.

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The Characteristics of Workers as Mediators in Knowledge Sharing Within a Company

Lourdes Sáiz-Bárcena, José Ignacio Díez, Miguel Ángel Manzanedo and Ricardo del Olmo

Abstract The importance of knowledge sharing to a company is such that it can, to a large extent, determine the success or failure of the competitiveness and survival of the organisation. One of the problems facing the management of knowledge, to ensure its application in the company, is the existence of barriers or impediments to effective exchange. Some of these impediments are due to the personality and personal circumstances of the employee, as well as certain management decisions, which have an influence on the willingness of workers to share their knowledge. The aim of this paper is to look at individual strategies that people employ so as not to share knowledge, as well as to identify certain management decisions and behaviour which may hamper this exchange. As far as the empirical work is concerned, a survey has been prepared, aimed at employees, unemployed workers and students in their final year at university, which was completed by a total of 1088 people. Some of the most pertinent results point to initial proactive attitudes towards knowledge exchange that weaken, depending on a person's age, their professional situation, type of contract, their salary, and their level of motivation. Similarly, the management decisions that contribute most to the success of knowledge sharing are ensuring good organization, a suitable organizational culture and climate, compatible leadership styles and fair recruitment, pay, and promotion policies in the eyes of employees.

Keywords Knowledge management · Knowledge sharing · Barriers to exchange · Personal characteristics · Management decisions

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1 Introduction

The application and recognition of knowledge within the company has given rise to major advances and important ideas, ensuring that knowledge management is constantly being improved and refreshed (Bolisani et al. 2012). In this regard, the cooperation of all involved is fundamental to the company's success (Erwee et al. 2012). Companies have developed their own knowledge, in order to differentiate themselves from their rivals (Dombrowski et al. 2012; Maruta 2012), ensuring greater growth and making the business more competitive (Abdelatif et al. 2015), as well as increasing productivity, reducing mistakes and improving profits (Guilló and García-Fernández 2013).

Occasionally, the employee's knowledge is not made explicit or communicated, as the person concerned feels that if they share it or pass it on, it might be damaging to them. This leads to significant business inefficiency and ensures that knowledge remains hidden and unspoken (Connelly et al. 2012; Lin et al. 2012; Yuqin et al. 2012), with the enormous cost that non-communication implies. This highlights one of the most problematic barriers to the transfer of knowledge (Paulin and Suneson 2012), which is sometimes the result of management decisions (Kukko 2013). Research into these barriers, difficulties and even instances of negligence in knowledge management may offer differing results, depending on the companies in question, the sectors in which they operate and even their geographical locations. Nevertheless, there are common and similar factors and arguments (Aghdasi et al. 2011).

The aim of this paper is therefore to look at individual strategies that people employ so as not to share knowledge, as well as to identify certain management decisions and behaviour which may hamper this exchange. To this end, the article is divided into four sections, in addition to this introduction. In "Theoretical Framework", the aims of the research are presented, with a brief summary of their most relevant aspects. The "Method" section describes the empirical research undertaken, including the sample selection, survey design and the statistical methods employed. The "Results" section offers a summary of the main results, which leads to the "Conclusions" section, with some of the most important reflections and consequences arising from this study.

2 Theoretical Framework

Sometimes, knowledge management in a company causes problems that mean that the required level of excellence cannot be attained (du Plessis 2008; Díez Pérez et al. 2014) In our case, we have focused on the barriers erected by human characteristics and behaviour, which may be due to gender, age, civil status, the person's cultural and educational background or the extent to which there is an attitude that is inclined towards the sharing of knowledge that is needed to work efficiently (Wang and Noe 2010).

These individual strategies may lead to a use of knowledge for personal benefit, seeking, for example, personal recognition (Zawawi et al. 2011), better incentives (Fitzsimmons and Stamper 2014), job protection (Hsu and Chang 2014), or in an attempt to outshine others. Experts, as opposed to the inexperienced, are sometimes less prepared to exchange knowledge, as they may feel that they have a unique and distinctive competitive advantage (Chen et al. 2013). The worker's age is also important, given that it alters their needs and aspirations within the company (Sáiz-Bárcena et al. 2013). This is also the case with priorities, which differ from person to person, and at different stages through-out our lives (Sáiz Bárcena et al. 2015).

All in all, human heterogeneity has been the subject of extensive research (Heineck and Anger 2010), as have areas such as diversity, organizational demo-graphics and the formation of multicultural and heterogeneous teams, analysing their strengths and weaknesses (Lin 2014).

Similarly, the implication and commitment of management and those in positions of responsibility within the company are of great relevance to the success of knowledge management (Özer and Tınaztepe 2014; Wu and Zhang 2013). Specifically, they have a significant bearing on factors that are of importance to the company (Fitzsimmons and Stamper 2014), as well as on decisions and learning from past mistakes (Gressgård and Hansen 2015).

Executive decisions are an essential part of knowledge management (Yang et al. 2010; Shan et al. 2013), and exert significant influence in all areas (Zhao et al. 2012), from identification, through sharing, to capitalization. Therefore, for ex-ample, certain management decisions cause bad relationships between staff members, when recognition and reward incentives are, for example, seen as unfair (Erdil and Müceldili 2014), which can lead to envy, jealousy etc. that then manifests itself in the workplace (Tai et al. 2012).

Another relevant factor is the type of employment contract and the job security that this represents (Huicho et al. 2012). In the case of temporary contracts, there are gender-based differences (Aletraris 2010), where men are prioritized over women and when awarding more stable contracts (Selvarajan et al. 2015; Rodríguez Gutiérrez 2012). The prevalence of temporary contracts is especially marked in the agricultural sector (Torres Solé et al. 2014), although the situation is still common in industry, as the first step toward a permanent contract (Centeno and Novo 2012).

The fact that the temporary nature of contracts affects people in important ways, and that not everybody accepts it in the same manner, is a very serious problem (Selvarajan et al. 2015). People employed on temporary contracts generally have a more passive attitude toward knowledge exchange, resulting in negative consequences for both the individuals concerned and the company (Stirpe and Revilla 2013), given that they feel inferior to others (Selvarajan et al. 2015). Finally, equity and fairness in the workplace are extremely important factors, given that they make a significant contribution to job satisfaction (Chiang et al. 2008) while the fair treatment of employees favours the sharing and transfer of knowledge (Tsay et al. 2014).

Table 1 Technical details of the research

Real sample population	1088 surveys
Minimum sample population	1065 people surveyed
Total universe	375,657 inhabitants (http://www.aytoburgos.es/)
Margin of error	3%
Level of confidence	95%
Heterogeneity	50% (worst case, extensive dispersion)
Selection method	Simple random sample
Scope	Burgos and its province. Employees, unemployed workers and final-year university students
Time period for survey	June 2012 to March 2013

3 Empirical Research

Our empirical research is based on a sample of 1088 employees, unemployed workers, and students in their final year at university from the city of Burgos and its province. An ad hoc survey was designed with 40 questions, based on the research of the authors cited in the previous section. A simple random sampling selection method was used, with the data gathered analysed using SPSS v19 software. The technical details of the research are summarized in Table 1.

4 Results

This research includes a summary of the results obtained from the study of frequencies and associations with respect to the questions concerning classification.

The results obtained were positive regarding the willingness to share knowledge, as 83.2% said they would, if it helped them gain promotion, while 93.7% answered that they would share knowledge voluntarily and teach others without receiving anything in return. As far as management decisions were concerned, those that ensured good organisation and organisational culture are the ones that most favour knowledge sharing (76%).

Table 2 sets out the personal characteristics and management decisions that most hamper the sharing of knowledge.

An age-based analysis reveals that young people are the most inclined toward knowledge exchange, although salary is also an influential factor (Table 3). Unfair appreciation and assessment of a person and the appropriation of ideas are two barriers that stand out from the others in this sample group.

Table 2 Personal characteristics and management decisions that affect knowledge exchange

Personal characteristics	%	Management decisions	%
Illness and personal situation	62.5	Poor leadership style	75.5
Appropriation of ideas	85.5	Existence of conflictive relationships	73
Knowledge that has required considerable effort to acquire	26.4	Bullying or mobbing	63.6
A feeling that an employee is expend-able	37.8	Unfair assessment of an employee	40.3
Low pay	50.7	Temporary contracts	43.9
Low level of motivation	37.1	Closeness to end of contract	60.8
Lack of reciprocity and trust	40.2	Incorrect assessment of performance	39.7
Potential consequences of redundancy	41.8	Last-in-first-out redundancy	51.5
Possibility of transfer	28.8	Lack of special skills	43.4

Table 3 Results of the association between age and the importance of pay

Would you share knowledge with someone who un-fairly earns more than you do?	18–30 years old	31–45 years old	Over 46 years old
Yes	43.58	55.33	53.35
No	56.40	44.64	46.64

As people grow older, priorities vary. We have seen that with older people, pay becomes a less important factor in terms of sharing knowledge. They also give less importance to the appropriation of their ideas by others.

Another important priority which changes with age is that of temporary contracts. Young people are more inclined to accept such contracts, while older people feel they are being unfairly used and under-appreciated. As employees grow older, temporary contracts become a significant barrier to the exchange of knowledge, particularly to the people who have the most to offer in this regard (Table 4).

Another barrier to knowledge sharing that is difficult to overcome and which becomes more marked with age, stems from the consequences of applying knowledge when this is harmful to the people who have passed it on. Inappropriate or humiliating styles of leadership represent a significant barrier to older employees, while younger staff appear to be more tolerant and less affected by the effectiveness of sharing (Table 5).

Table 4 Results of the association between age and the importance of temporary contracts

Would you share knowledge if you were given a temporary contract?	18–30 years old (%)	31–45 years old (%)	Over 46 years old (%)
Yes	60.94	53.14	48.2
No, I would feel, I was being used	24.34	25.48	30.05
There is no contract extension	14.72	21.37	21.76

Table 5 Results of the association between age and the importance of leadership style

Would you share your knowledge within a context of poor leadership?	18–30 years old	31–45 years old	Over 46 years old
Yes	28.11	23.55	16.62
No	71.89	76.45	83.38

5 Discussion and Conclusions

The aim of this research has been achieved, insofar as we have identified the individual's characteristics and personality attributes which may have a bearing on the effectiveness of knowledge exchange within the company. We have also been able to highlight some of the executive decisions that have the most positive influence on knowledge sharing.

The priorities and needs of workers may determine the success or otherwise of knowledge sharing and capitalization. This research has shown how a person acts when there is knowledge exchange within a company, when that person is ill, when their ideas are appropriated, where the knowledge to be shared has cost them considerable time and effort to acquire, where they feel they might be expendable, where they are unfairly paid or they lack motivation.

Management decisions are also highly influential in ensuring willingness towards sharing. Our research has highlighted the importance of ensuring good company organization, as well as a positive working atmosphere and organizational culture. Management style, the building-up of good relationships, preventing bullying and mobbing, eliminating temporary contracts, putting an end to job insecurity and a commitment to a fair recognition of employees are all of significant help in ensuring that the sharing and transfer of knowledge is a reality. Finally, the study of associations shows that the age of the person is a factor that affects knowledge sharing, in such a way that within a context of unfair pay conditions, older employees share more, whereas in the case of staff on temporary contracts, young people are most inclined to exchange knowledge, as they are in situations of poor leadership.

All of these results are of great importance, in order to move forward with our research and the application of the conditions that most favour knowledge exchange and sharing within the company.

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Project Management Success Factors in Basque Companies

N. Zabaleta, M. Ruiz and U. Elorza

Abstract Project management discipline has undergone significant changes in the past decades (Hanisch and Wald in Project Management Journal 42(3):4–22, 2011). The project management influencing factors have been the subject of empirical studies. This paper examines the link between some of these factors and project success, through a survey with the participation of 121 project managers in the Basque Country in Northern Spain. The most important result of this study is the relevance of project manager skills and characteristics, and their influence on project success.

Keywords Project management · Project success factors

1 Introduction

As central element in the process of innovation, project management has become a key activity in most industrial organizations and across many industries (Shenhar and Dvir 1996). Furthermore, innovation management is a major application field of project management (Gemünden 2015). Although projects have existed since the beginning of civilization, it is an activity that emerges as a discipline in the twentieth century and acquiring greater importance in recent years.

The direction taken by the global enterprise activities justifies the relevance of projects. It is also expected that the trend to work for projects will continue to grow in the future (O'Neal et al. 2006; Shenhar and Dvir 1996; Stoneburner 1999). In these circumstances, the ability of organizations to develop their key project activities effectively and efficiently becomes an important competitive factor (Mathur et al. 2007; Pinto 2002).

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Based on a sample of 121 project managers from Basque Country companies, the interactions between project management factors and final success are analyzed in this study.

2 State of the Art

Different studies show the importance of project management in improving innovation, competitiveness and change processes:

- A project aims to achieve a product/service or result (Project Management Institute 2013) and therefore involves novelty and risk. Similarly, projects are a critical element in organizational success.
- Managers and experts have stated that project management is the subject of the future (Gray and Larson 2006), as projects today are considered much more than just solutions to technical problems.
- Projects also provide a means to better perform changes (Andersen and Jessen 2002).
- Projects increase sales, reduce costs, improve both quality and customer satisfaction and improve working environment (Kerzner 2001).
- Shenhar and Dvir (2007) say that projects drive business innovation and change; in fact, the only way that organizations can change, implement a strategy, innovate and gain competitive advantage is through projects.

Some research studies and articles have reported on the critical success factors for project management success. Some of these factors have motivated the investigation reported below.

2.1 Project Type

One of the most important projects classifications was developed by Shenhar and Dvir in 2007. These authors establish a classification of project types based on 4 axes (Novelty, Complexity, Technology Uncertainty and Pace). This model is called "NCTP model" or "Diamond Framework" among experts in project management and in academia. Each project can be classified based on those 4 axes (Novelty, Complexity, Technology Uncertainty and Pace), forming a "diamond". The larger the diamond, the greater the risk the project entails. This four dimensional model has been used in this research.

2.2 Organizational Structure

It is widely agreed that the choice of management structures used to implement innovative, temporary, cross-functional and complex project endeavours has important implications for project success (Lechler and Dvir 2010).

Organizational structure can affect the availability of resources and influence how projects are conducted. Taking into account the classification developed in the Project Management Institute (2013), organizational structures range from functional to projectized, with a variety of matrix structures in between.

This is the predominant approach defining alternative forms of project management structures and it follows Galbraith's (1971) conceptual differentiation between three basic structural types. At one extreme, in the functional organization, project managers do not have project decision authority, whereas at the other extreme, within the projectized organization, they have full decision authority. The matrix organization is positioned between these two extremes (Lechler and Dvir 2010).

2.3 Project Manager Characteristics

According to the most recognized global standard in project management, the Project Management Body of Knowledge (PMBoK), effective project managers need to have a balance between their ethical, interpersonal and conceptual skills that will help them to analyze situations and interact appropriately (Project Management Institute 2013).

Malach-Pines et al. (2009) and Tobal et al. (2012) collected these variables related to the character, knowledge and skills of people working on projects, concluding that people directly influence the outcome of these proceedings.

2.4 Project Management Maturity

Some organizations are just getting started with project management. Others have reached a level of maturity whereby project management has become a way of life (Kerzner 2001).

Organizations must find ways to document their best practices and learn from others, to identify differences that help them become more competitive through continuous improvement using control measures and progress.

Kerzner Project Management Maturity Model (2001) stands out from other models because it is an assessment tool for each level that can be customized according to the type of organization. The Kerzner model provides 5 levels that have been analyzed in the current study.

2.5 *Project Success*

There is a remarkable difference in the perception of the meaning "success" in the minds of people who evaluate project performance (Ghasabeh and Chabok 2009). Traditionally in the project management literature, time, budget and meeting end product specifications have been the main indicators of project success. These measures are incomplete and may be misleading, as, although they may count as 'successful' projects in that they met time and budget constraints, they failed, however, to meet customer needs and requirements (Malach-Pines et al. 2009). Four dimensions proposed by Shenhar et al. (2001) and Malach-Pines et al. (2009) are used in this study:

- Meeting planning goals (Efficiency)
- Impact on the customer (Customer's perspective)
- Benefit to the developing organization (Organization's perspective)
- Overall, success was based on averaging the three success measurements.

3 Research Methodology and Study

Taking into account the research objectives, the methodology was based on a questionnaire comprising some 85 questions covering 4 project management factors that have an influence on project success. Some of the questions were selected from the work developed by previous authors cited in the State of the Art.

The research work was based on a questionnaire completed through a survey carried out with 121 project managers from 63 companies in the Basque Country (Northern Spain). It could be said that the most relevant Basque enterprises and industries were represented in this study. The project managers were from different industries, including Energy (25% of the respondents), Automobile (22.95%), Construction (21.31%), Software (21.31%) and Machine Tools (18.85%) among many others. The respondents had an average of 12 years working as project manager in their current company. The questions were designed as closed questions. In order to obtain the most reliable results possible, it was ensured that the questions were properly understood and fully completed.

With the aim of simplifying the statistical analysis, a number of composite variables were built from the replies obtained. The key variables utilized for the analysis were as follows: The project type (V1), the organizational structure (V2), project manager characteristics (V3), and the company project management maturity (V4). V2, V3 and V4 were optimized and calculated through a combination of single variables (α Cronbach = 0.768–0.964).

As regards the output variable, Project management success (V5) was selected as a combination of 11 questions (α Cronbach = 0.820).

Different sectors showed different project type diamonds according to Shenhar and Dvir's (2007) classification. High tech industries (Aeronautics or Pharmaceutical companies are included in this group) displayed the largest diamond and Low-Tech (Food, paper or furniture) industries the smallest. The largest group of projects were new product development projects, followed by R&D projects and construction projects.

Taking into account the organizational structure, 31.40% of the respondents worked in Functional organizations, 35.54% in weak matrix organizations and finally 33.06% of the participants belong to Strong-Matrix or Projectized organizations.

Following the Kerzner (2001) classification of project management maturity levels, none of the respondents was in level 1, 13.22% were in level 2, 38.02% in level 3, 35.54% in level 4 and, finally, 13.22% were in level 5.

Considering the output variable, project success, and the work developed by Malach-Pines et al. (2009) three success dimensions were used: meeting planning goals (project efficiency), impact on the customer (customer's perspective), benefit to the developing organization (organization's perspective), and overall success representing an average of the three success dimensions. Respondents evaluated customer perspective as the best dimension and the organization's perspective as the worst one. So it can be concluded that the project meets customer requirements but the project efficiency is not so good and the benefits to the developing organization must be enhanced.

4 Results

Correlations of the model variables are provided in Table 1. Project type, Organizational Structure, Project Management Maturity, and Project Management Characteristics exhibit high correlation with Project Success. At the same time, all the independent variables show a high relationship between them.

Once it was found that all the independent variables correlate with project success, regression analysis was performed to test the statistically significant contribution of these project management factors to project success. Table 2 summarises the results from regression analysis.

The model showed that project manager characteristics have significant relationship with project success and the relationship was positive (Beta = 0.404, $p < 0.01$). It is the variable with the highest impact on project success.

Observing results, it could be pointed out that even though all the independent variables contribute towards project success, project management characteristics have the most influence.

Table 1 Pearson correlation results

		Project type	Structure	PM maturity	Project manager	Project success
Project type	Pearson correlation	1	0.323**	0.201*	0.314**	0.253**
Structure	Pearson correlation	0.323**	1	0.655**	0.195*	0.317**
PM maturity	Pearson correlation	0.201*	0.655**	1	0.325**	0.368**
Project manager	Pearson correlation	0.314**	0.195*	0.325**	1	0.492**
Project success	Pearson correlation	0.253**	0.317**	0.368**	0.492**	1

** $p < 0.01$, * $p < 0.05$

Table 2 Regression analysis

Independent variables	Standard beta
Project type	0.056
Structure	0.127
PM maturity	0.142
Project manager	0.404**

** $p < 0.01$

5 Discussion and Conclusions

The main purpose of the article was to identify the link between project management factors and project performance results. Four project management factors (Project type, Organizational Structure, Project Management Maturity and Project Manager Characteristics) have been cited. All the data collected for this study was quantitative, originating from a survey with 121 project managers.

The study shows that the project type, the project manager skills, the organizational project management maturity and organizational structure have influence on the overall outcome of the projects. Nevertheless, special attention has been paid to project manager skills and characteristics. The findings suggest that project managers showing high values in the skills listed here, presented better results in project success: project managers who love challenges, committed project managers, involved project managers, creative project managers, persistent project managers, realistic project managers and self-confident project managers. Therefore, considering that independent variables correlate positively between them, it could be pointed out that projects managed by project managers whose personality matched their project type will be more successful than projects managed by project managers whose characteristics do not fit their project type. These results support earlier researchers' findings (Malach-Pines et al. 2009; Tobal et al. 2012).

As regards project management maturity, considering this variable with values between 1 and 5, the nearer the highest score, the better the project results. This variable is also directly related to the organizational structure, and more mature organizations in project management also show a stronger matrix or more projectized organizational structures with their project managers enjoying higher levels of authority (Lechler and Dvir 2010). In brief, organizations that are closer to strong-matrix or projectized structures reveal better project success.

The limitations of this paper result from the small number of variables used. Further research and analysis would provide more detailed links. On the other hand, the contributions of this study must be interpreted with a degree of caution since it has focused on the Basque context, which may have certain characteristics that can affect the final performance.

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Integration of Constructability and Project Risk Management

L. Farina, E. Danesi, A. Travaglini, Mauro Mancini and P. Trucco

Abstract The research concerns the EPC world and Mega-Projects. The focus is on two disciplines: Risk Management and Constructability. An innovative integration model is proposed, aiming to bridge the existing gaps, to support a structured decision-making process and to facilitate the integration of the two disciplines characterised by different approaches and competences, but with a common target: the megaproject success. The validation of the model is carried out by mean of a cost/benefit analysis on four case studies of an EPC contractor (Saipem SpA).

Keywords EPC contractor · Construction · Integration · Constructability · Project risk management

1 Introduction

Nowadays EPC contractors have to deal with increasingly complex projects, characterized by fragmented and articulated processes. The development of appropriate tools and techniques is necessary to make the project management efficient and to avoid waste in terms of time and resources. Othman (2011) states that most of these problems can be overcome by implementing procedures that focus on techniques for the improvement of project quality and efficiency. In particular, the main arguments of this research are. Academics and practitioners have explored Project Risk Management (from now on PRM) and Constructability (two disciplines largely adopted by EPC contractors since the 90s) separately, but there is a big gap on their integration.

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2 Research Problem Definition

Construction projects are often part of a complex and dynamic environment, resulting in circumstances of high uncertainty that could threat the project success. PRM cannot disregard the construction activities since the major part of over-costs and delays comes from construction inefficiencies (Zhao and Duan 2008). Schieg (2006) asserts that the integration of a PRM system must permeate all areas, functions and processes of the project. Hiley and Paliokostas (2001) argue that there is the need to structure a better relationship between PRM and Constructability processes, because promoting the latter can in turn reduce specific risks. This work answers the following research questions: (R1) What is the State of Art of PRM and Constructability and what is their degree of integration? (R2) How can the disciplines be integrated to improve the efficiency and effectiveness of the project processes? (R3) If the feasibility is proven, what are the costs and benefits of the integration?

3 Research Methodology

The followed research process complies with the guidelines proposed by several literature sources such as Kumar (2011). Adopted process steps are shown in Fig. 1.

Each step answers its related research question. The aim of literature survey (M1) is to understand the disciplines' state of art and the research progress about their integration. Both conceptual and empirical analysis has been reviewed. Moreover, previous research has provided explorative guidelines for the creation of a theoretical model (M2) where Constructability and PRM processes are integrated. The main reference standard is the IDEF 0, fit for function modelling. By integrating the theoretical model concepts into Saipem's[1] procedures, a time-dependent model has been developed (M3). After defining cluster domain for case studies, the model validation has been developed in four projects[2] subjected to a cost/benefit analysis. Figure 2 shows the data collection and the analysis development.

Data about construction criticalities (due to the lack of integration) have been collected from internal documentation and interviews with personnel involved in the examined projects. The triangulation of evidences (Yin 2012) from multiple data sources and the investigator triangulation (Bryman 2004) results in the process.

Within-case analysis provides (i) costs calculation of model application depending on boundary conditions of the project through a proper spreadsheet

[1]Nowadays Saipem SpA is the Italian leader EPC contractor in Oil & Gas sector.

[2]Among the projects characterised by being closed, recent, data abundant, covering the cluster domain and with criticalities not strongly influenced by big company-independent issues, the cases have been chosen through judgment sampling, aided by company experts.

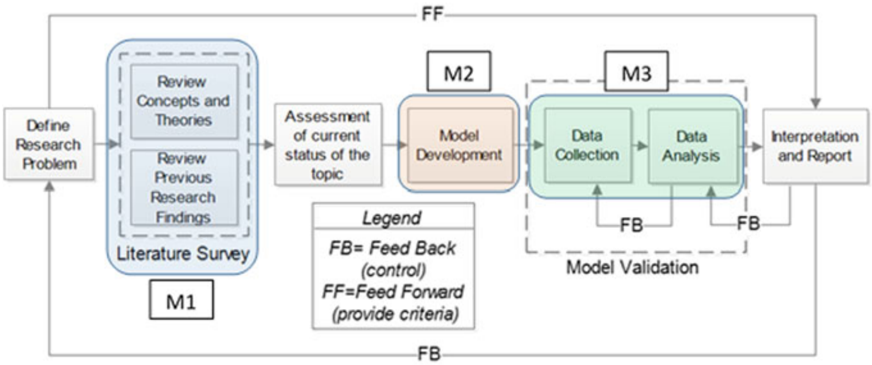

Fig. 1 Research methodology process

Fig. 2 Data collection and data analysis

(developed thanks to interviews and analysis of past project resources) (ii) cross-checking the issue data (qualitative and quantitative) against related Risk Registers, ROBS, Constructability Log and Checklist. Extra-costs of such issues represents the virtual benefits of model application. *Cross-case analysis* concerns instead (i) identification of macro similarities and differences between cases (ii) estimation of model convenience patterns on the established domain.

4 Findings

The outcomes of M1 (R1) are the states of art of the disciplines (singularly) and the explorative studies about their integration. Constructability definition dates back to 1986 by the Construction Industry Institute as the optimum use of construction knowledge and experience in planning, design/engineering, procurement, and field operations to achieve overall project objectives. Some principles[3] are reported for a proper Constructability Program development are the following: Integration, Site Layout, Construction Methodology, Planning, Flexibility, Availability of resources, Feedback, Contracting Strategy. To achieve the major benefits,[4] Constructability shall take place at earlier design stage (Zolfagharian et al. 2012) overcoming barriers such as complacency with the status quo, reluctance to invest resources in early project stages, limitations of lump sum competitive contracting. Many authors (e.g. Hillson and Simon in 2007) and institutes (APM 2012; ISO 2009) generally agree upon the meaning of the word "risk". Several authors (e.g. Gajewska and Ropel 2011) consider the management of project risks as a key discipline for EPC contractors and their competitive advantage. EPC general contractors need a high level of PRM because they have two huge components of risk in the bidding decision-making phase: one part is the risk deriving from the design scheme and the other part is the risk stemming from the bidding offer. Moreover, Mohebbi and Bislimi (2012) and Hiley and Paliokostas (2001) recognise the importance of getting the (PRM) processes started since the early steps of the tendering. Other authors define barriers to the proper PRM. Kutsch and Hall's (2010) research asserts that the strong willing to win the tender and the deliberate ignorance ("irrelevance") of personnel involved in the identification implying the negligence of some risks, turning RM into ineffective or counterproductive. Mohebbi and Bislini (2012) indicate that many companies properly invest in RM systems only after the contract award. Since the early 2000s, few literature contributes have been dealing with the integration between Constructability and PRM. Whenever discussed, it is often cited as part of the integration between Value Management (VM) and PRM. VM is a multidisciplinary effort towards achieving the best value at the lowest overall life cycle cost, in according with set criteria. Value Engineering (VE), moreover, is recognised as a "hard approach" of VM. Mootanah (1998) defines it as a systematic approach to deliver the required functions at the lowest cost without detriment to quality, performance and reliability. Constructability has the same objective as VE, but concerning the construction discipline. While VE aims to reduce the total life cycle cost of a facility, Constructability focuses upon optimization of the entire construction process. In particular, Hiley and Paliokostas (2001) assert that the integration of PRM and VM would enhance the outcomes of both procedures and improve decision-making: PRM adds a further dimension to the evaluation of VM proposals, VM can improve the effectiveness of risk responses through creativity.

[3]To see a more complete list, please consult Nima, M., Abdul-Kadir, M. and Jaafar, M., 2001. Evaluation of the role of the contractor's personnel in enhancing project constructability.

[4]The benefits of Constructability are multiple, e.g. minimized contract change orders, reduced project cost and duration, enhanced project quality, increased owner satisfaction, and higher trust among project team, as well as a better design and a more effective construction planning (Pocock et al. 2006).

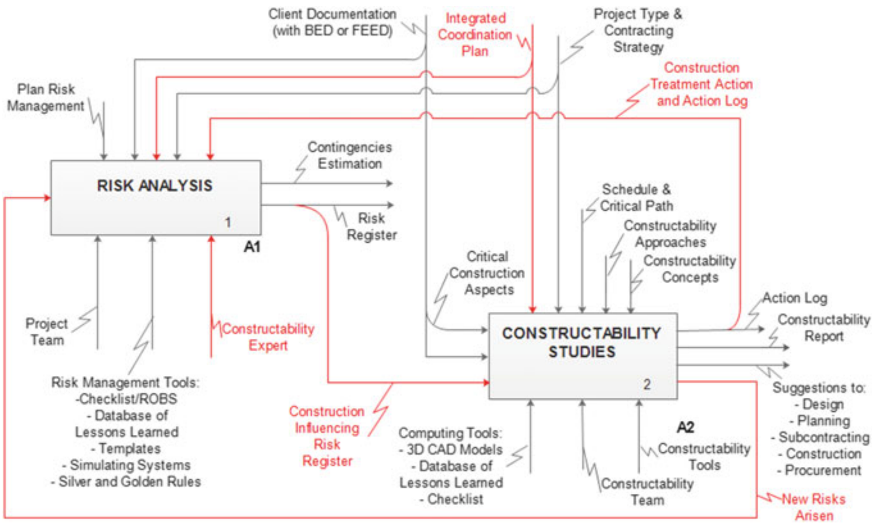

Fig. 3 Theoretical integrated model

Integrated Model Development. The PRM and Constructability embrace all the aspects[5] of the projects, but they look at the criticalities with different objectives. While the PRM aims to evaluate a critical aspect in terms of potential economic impact on the project, the Constructability is more technical. In this sense, they can complete each other. A conceptual model aiming to overcome the recognized barriers—e.g. the short time available to prepare the bid, reluctance to invest additional resources in early project stages, inadequate lessons learned collection, scarce effort on closeout reports draft—shows the logic behind the integration and how the two disciplines can exchange information (R2). Its objective is to design the most flexible solution to face a risky situation. It does not want not to revolutionize the two discipline, but to improve and bridge the gap between them. It considers information, personnel and tools exchange. The right information has to be provided at the right time (mature enough to allow a specific study) and to the right person. The relationship between functions has been modeled through the IDEF 0[6] standard (Virginia Department of Commerce 1993).

The proposed model is applicable to any EPC contractor and it can be implemented in the bid or executive phase, for any kind of project. The innovative characteristics of the model in Fig. 3 are: (i) *integrated coordination plan* shall rule the timing of information exchange (previously approved) and shall contain the information (lessons learned and closeout report) from similar past projects

[5]RM and Constructability involve external environment, laws, financial/economic aspects, engineering, procurement/subcontracting, the execution plan, construction/installation, safety.

[6]Each function box, processes the inputs (by left side) to create outputs (coming out from the right side). Controls enter in the upper side of the box, whereas mechanism from the lower side.

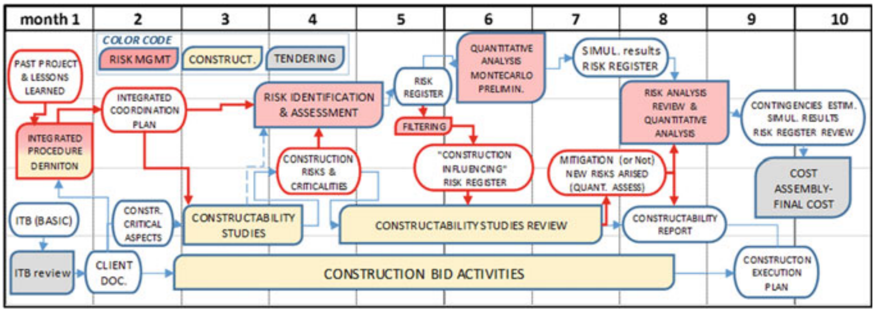

Fig. 4 TO-BE model in saipem

(ii) *Construction treatment action and Action Log* (Constructability's corresponding document to the risk register) through its technical competence and studies, it can treat the construction risks (iii) *Constructability expert* can highlight criticalities of construction activities. (iv) *New risks arisen* come from the construction criticalities suggested by Constructability studies. (v) *Construction influencing Risk Register*, so that only the list of potential risks impacting the construction phase would be treated (e.g. procurement risks of a critical item). Saipem SpA has allowed the application and the validation of the model on its internal procedures (R3). Constructability is not enough developed during the bid phase due to time constraints, whereas it is broadly used during the project execution. PRM is always performed even in the bidding phase but it is often mainly based on qualitative information. Consequently, the integration of the two disciplines is very little. Business Process Modelling technique has been used to represent the Company's activities. The AS-IS model, by inserting the IDEF 0 model (red slots and arrows), becomes the final TO-BE (integrated) situation (Fig. 4).

Case study domain. The consultancy of company experts has resulted in the selection of two parameters as mostly influencing the effort on Constructability and PRM (Fig. 6): (i) project dimension and technical complexity (Construction SMH[7]) (ii) complication of boundary conditions (Overall Project Complication). They are the two axis of the domain. X-axis reflects the overall project complications, which is a combination of several weighted factors.[8] As an example, one case study—a revamping project (Proj. 4)—is presented in the following paragraph. Its project team had to deal mainly with two critical aspects that reduced the constructability of the plant: limited space and interface with the existing working plant. All the costs and benefits monetary values are indicated as percentage of the total project value for business policy reasons of the company.

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[7]Construction Standard Man Hours do not consider the delocalization and the productivity factors, but are an index consistent with the dimension and construction complexity of the project.

[8]Spatial availability, interference with running plants, Saipem SpA presence in the country, country industrial development, soil and geotechnical characteristics.

Table 1 Revamping project (Proj.4)—issues summary

Issue description	Integration improvement
Belt conveyor structure foundations. The client could not provide the "as built" of the area for the bearing structure of the conveyor. At first, the engineering considered the installation of classic foundations. After the excavation works, the space available was revealed to be not sufficient because of the interference with foundations of existing facilities	The risk is identifiable by a Constructability study, e.g. plot plan review or a checklist review. The uncertainty shall make the risk analysis start, allowing the project team to prepare a mitigation strategy. Examples of risk responses are: put an extra contingency; consider a clause in the contract to deflect the eventual extra cost to the client
Contaminated groundwater. The unexpected amount of contaminated groundwater led to waste of resources, extra costs and delays	Similarly to the previous case, the Constructability could have identified this issue since it is mentioned in the checklist

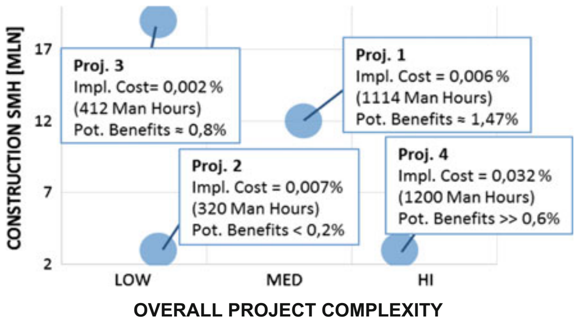
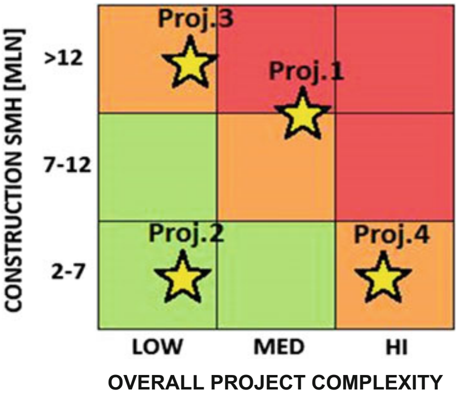


Fig. 5 Cost and potential benefits for each case study

Table 1 reports some of the construction issues,[9] underlining the constructability studies importance to identify the risks related to the project. The integration model implementation facilitates a more proactive approach. The PRM outcome is to change many *unknown unknowns* into *known unknowns* and manage them. The extra budget (issues effects) is due to: (1) delays of the subsequent activities in the same area and re-engineering man-hours for foundations. For example, just the extra material costs (piling) represents about the 0.06% of the entire project value. (2) unforeseen costs of second issue represent the 0.61% of project value (excavation of ponds for contaminated water, water transport costs, external water treatment, wrong treatment package) plus the delays of foundations installation. *Cross-Case Conclusions*. A significant trend is identified in the cluster domain (Fig. 5). For a project in the bottom-left area of the domain, the model benefits could be negligible since the construction inefficiencies are probably not very impactful. The required costs of implementation are very low (right lower than 0.007% of the project value), so they would be easily paid back. With the increase of project complications and

[9]An occurred risk becomes an issue.

Fig. 6 Cluster domain



(above all) dimension, *convenience* becomes gradually more evident because the same issue has bigger economic and time impact.

Within-Case Conclusions. The estimated delta (between the AS-IS situation and the TO-BE) cost[10] for model implementation is about 0.032% of the project value and it is calculated by mean of the spreadsheet previously mentioned. The "virtual" saving of the issue cost can be considered as the benefit of the model application (excluding the qualitative ones) and it always exceeds the costs. The most impacting factor on the *implementation costs* (Fig. 5) is the "Overall Project Complexity". Obstacles such as spatial constraints, interferences with other plants, a poor industrialization level, soil conditions and a scarce knowledge of the country require a strong effort especially on constructability evaluations.

5 Conclusions and Further Research

Three main results can be highlighted. PRM and Constructability are well described by the academic world taken individually, but little has been discussed about their integration (R1). The proposed model provides the integration between the two disciplines procedures (R2). The model is applicable to a contractor's internal procedure. Its convenience has been demonstrated for different kinds of projects especially for those with high technical complexity and/or complicated boundary conditions (R3). The provided validation concerns only the onshore world. Further research could replicate this analysis within other branches, such as offshore and drilling projects. While building the cluster domain, differences between upstream and downstream typology have not been considered significant. Further research

[10]The number should not be considered by itself: current internal statistics have revealed that the Contractor has a ratio of 1 contract award out of 10 bids. The implementation cost shall include the additional resources spent for the unsuccessful bids as well.

may study the actual significance of this factor, maybe using a wider sample of projects and other experts' opinions.

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Part VII
Service Systems

Sustainability Leveraged by Energy Service Projects (ESCO) in Spain: Analysis 2010–14

Jesús Morcillo-Bellido, Bernardo Prida-Romero and Javier Martínez-Belotto

Abstract Sustainability is currently a common term, although in many cases it has been used not in the proper way and sometimes even inappropriately. Currently, both academics and business executives broadly understand the sustainability as a challenge that involves not only environmental aspects, but as an integrative concept including economic, environmental and social aspects that should be the basement to build the pillars of the most competitive companies in the twenty first century. Authors of this study have done a detailed and deep study on a sample of two hundred "Energy Service" or ESCO projects in Spain in order to understand if they got visible sustainability improvements in a comprehensive point of view (from economic, environmental and social angles). Being these projects those in which two companies make collaborative arrangements to implement energy efficiency improvements, and both companies results are based on integral saving sharing.

Keywords ESCO projects · Energy service projects · Supply chain sustainability

1 Introduction

The need to carry out practices that do not endanger the environment is relatively new, but also it rapidly gaining relevance. According to some authors (Chouinard et al. 2011) the problem is that usually it is cheaper to buy a product or service that

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has a detrimental impact on the environment because the additional cost—via environment impact—is not directly transferred to the customer purchasing price. Simultaneous globalization and worldwide consumption rise happened in the last decades has contributed to an unprecedented growth of the world economy and to a relative decrease of global poverty (Norberg 2003, 2005; Olivié 2005). Based on this economic change large geographical areas like China, Vietnam and Malaysia have managed to grow into levels heretofore unknown as they are performing industrial activities previously carried out in Europe and North America and participating in the growth of global consumption, and this has caused a major change in global supply chains (Govindan et al. 2014).

The term "sustainability" began to emerge in the economic literature within management and operations disciplines (Carter and Rogers 2008) in late twentieth century, from sustainability original definition stablished by the well-known Brundtland Commission (WCED 1987). These authors consider that economic, environmental and social angles make a whole platform that it has been called in the literature as "triple bottom line" or "integral sustainability", which corresponds to the idea of taking into account the simultaneous prioritization of the three outcomes (economic, environmental and social) into firm's management. The initial integral point of view was developed by Elkington (1998, 2004) when considering as "sustainable" the organizations that manage and support simultaneously activities leading economic, social and environmental aspects. Already in 2004, about 68% of the top 250 global companies published their sustainability reports, which included aspects related to the above mentioned angles and 80% of the issues addressed in these reports were linked to supply chain (KPMG 2005). Supply chain could be described as various entities linked from the customer to the supplier, both in manufacturing and services (Stevens 1989; Viskari and Karri 2013). To be considered as supply chain is essential to integrate management practices that promote proper chain objectives achievement such as cost, quality, service and reliability. Nevertheless, practices must go further than economic focus, also including social and environmental aspects (Alzaman 2014). Supply chain management must integrate the three angles, and ultimately all those aspects that have to do with sustainability understanding as an integral view (Carter and Rogers 2008).

To find potential ways to encourage the development of practices that support sustainability and converts those practices into a strong engine of business growth is a priority for both academic researchers and executives. It has been published a study (McKinsey 2012) of more than three thousand online interviews to worldwide business executives and from this study could be concluded that the three main topics that companies usually consider to improve business sustainability are: (i) energy consumption reduction in whole supply chain (66%), (ii) reduction of waste in the supply chain (64%), and (iii) corporate social responsibility (57%). The first aspect is linked to energy management improvements and environmental impact through lower CO_2 emissions, the second is also related to the environment and cost reduction and the third is linked to social parameters.

Regarding energy efficiency issue, in recent years it has been developed a type of collaborative relationship that has shown a clear way to improve energy efficiency, thus being one of the active agents in the economic and environmental sustainability. Thus in recent years there have been companies entering into agreements with other organizations to optimize energy management, ensuring service level, improving comprehensive costs and getting an integral result far better than acting alone. These companies are called “Energy Service” or “ESCO”, and they invest in more efficient technologies and installations, maintain and fund them eventually seeking maximum efficiency and ensuring agreed service level (Vine 2005). Within European Union strategy there is a clear support for partnerships between private and/or public organizations to achieve comprehensive significant energy savings (usually 30% to 60%) by integrated “energy service projects” (Morcillo and Prida 2014). The different types of contracts that exist in the ESCO relationships (Langlois and Hansen 2012) helps to understand this type of collaboration: (a) Energy Supply Contract (ESC), in which the ESCO provides to the customer transformed energy (heating, hot water, etc.) in a specific facility managed by ESCO itself (Bertoldi and Rezessy 2005). Usually ESCO retains equipment ownership, assumes the risk of energy price and installation performance, (b) Energy Performance Contract (EPC) with two alternatives: (i) “shared savings” when ESCO supports the technical risk but the financial risk is kept by the customer, and ESCO gets revenue as a portion of the savings if any, (ii) “Guaranteed savings”, the client assumes the credit risk, but the ESCO guarantees some savings and they must pay the difference (vs. agreement) to customer, (c) Build-Own-Operate-Transfer (BOOT), in which the ESCO designs, builds, finances and operates the equipment installed during the contract length, and (d) Integrated Energy Contracting (IEC) that model is to combine EPC and ESC and tends to increase the level of savings in operations (Bleyl 2012).

The study of this relationship (via ESCO project) is definitely an opportunity to know in what extent this cooperative relation is adding value to the supply chains sustainability of companies linked into this type of projects. For this reason, the authors have tried to study to what extent is possible to infer practical sustainability results/practices into a sample of ESCO projects that have been developed in Spain during last years.

2 Objective and Study Methodology

Authors of this paper are interested in getting deeper knowledge and understanding about the sustainability impact of Spanish ESCO type projects during the period 2010–2014, and specially about some specific questions like: (i) what kind of business model are applied in Spanish ESCO projects, (ii) characteristics of these type of projects in Spain (application, ownership, financial payback,…) and (iii) how these collaborative projects contribute to sustainability, in terms of project economic impact (energy savings) and CO_2 emissions reduction.

Authors have used qualitative research methods, like secondary data analysis and in some case studies (6), that Yin (1989), Eisenhardt (1989) and Gummenson (1991) consider as appropriate for the exploration of innovative aspects in organizational management as it could be considered firm's sustainability. Information has been obtained through: (i) published project's data, (ii) semi-structured interviews to executives from several institution (ANESE, Ministry of Industry and IDAE, Philips and Endesa) and (iii) the study also combine direct involvement of an author in real ESCO projects which could be considered like proper action research and right information source, that helps for better understanding of data (Coghlan and Coughlan 2008) and could enrich study outcome.

Study was focused in the period 2010–2014, through detailed analysis of 223 different projects carried out in Spain during this period, by more than 80 companies engaged on them. The total number of companies carrying out such type of projects in Spain is unclear, since there is no official data. According to some authors the number of ESCO companies in Spain could ranges from 200 to 600 (IDAE 2015) and it has been estimates that total annual energy services projects in Spain could be 500–600 and a turnover of 900–1000 M € (D'Andretta 2014). Project selection criteria was fixed as "projects starting date" during the period 2010–2014, and as consequence it was only suitable to analyze real data results in around twenty percent of sample (43 project) while data collection in the rest was based on published expected results. For each individual project it has been extracted some field data (see Table 1).

As far as authors could check, based on real data analysis, there was a minor deviation between reality and forecasted results within finished projects, and this means that analysis based on planned data seems to be very accurate and valid.

Table 1 Data collection from field study

Data	Comments
Size	ESCO project size (project value)
Location	Comunidad Autónoma/city
Ownership	Public and private
Application/segment	Activity (i.e.: offices, hotels, hospitals,…)
Technology	Technology applied (ejemplo: iluminación)
Types of agreement	Type of contract applied to agreement (i.e.: EPC model)
Length	Contract length
Budget	Project budget
Savings	Energy savings (kWh/CO_2 tons per year)

Source Own elaboration

3 Results Analysis

3.1 *ESCO'S Model Within Spanish ESCO*

From project's analysis is possible to conclude that the average investment per project worth 1.75 million €, and 39% follow an EPC model, 18% apply an IEC model, 7% use the ESC model and another 28% the rest of alternatives. Analyzing the data from the EPC projects, most of them (85%) belong to guaranteed savings business model, while the rest are shared savings model. This data proves that Spain is closer to other mature markets (Wagner 2010).

3.2 *Most Common Application and Ownership*

At European level, in larger countries (as Germany and France) technologies related to air conditioning are the most applied in energy saving projects (Bertoldi et al. 2014). From sample analysis the most common applications are: air conditioning (64%), energy management systems (54%) and lighting (49%), and their main application areas are office building, entertainment, hospitals, schools and public lighting (councils).

Large companies (considering as such those with over 250 employees) have carried out 58% of the projects analyzed. But this majority is not as overwhelming as in France and the UK, where more than two thirds of the market is controlled by large companies (Bertoldi et al. 2014), in Spain medium and small companies control a significant market share. Nevertheless comparing the difference on company investment, large companies invest as average 2.5 times per project more than SMEs. Large enterprises market share in the public sector is much higher than in the private one, while SMEs are more likely to develop projects in the private sector, the route cause could be found in high barriers to adapt themselves to the structures and methodologies required by governmental entities, where processes used to be slow and inefficient, driving in some cases into long negotiation processes or even stopped projects after many months of hard work. During the analyzed period (5 years), 56% of projects value was carried out in the private sector, while the remaining 44% were performed in the public sector, although in the last two years the public sector projects business outpaced private, both in number of projects and the value thereof. It is relevant to recall that in the most important countries the public sector is the biggest one (Bertoldi et al. 2014; Carvallo et al. 2014). Public sector projects are mainly carried out in municipalities, and mainly focused on street lighting renovation.

3.3 Projects Length and Financial Pay Back

There were analyzed contract's duration within the sample and it possible to conclude that the average ESCO length is almost ten years. The reason that seems to explain why energy efficiency contracts use to have a duration so pronounced is the extended recovery period required for these investments. Within the projects studied in the sample the financial recovery period was almost eight years. The difference of two years serves to get some ESCO net income before the installation (including all the added investments) return to client control. From collected data it has been studied the so called "financial return rate" of the projects in this sample—this ratio measures the relationship between the "average net present value" and the "average investment" needed to carry out them—getting as result a the average ratio is 1.34 on investment. This means that the ESCO projects analyzed have an acceptable "profitability" index.

3.4 Impact on Sustainability

To measure sustainability impact it is necessary to measure projects outcome from the three angles of "triple bottom line", so their economic, environmental and social impact. Based on project data, it is possible to estimate contribution of this bunch of ESCO project to sustainability through their economic and environment impact:

Energy savings impact. It has been analyzed the energy saving impact on the sample (energy consumed before and after ESCO project implementation, indicated in each project data base) and it follows that the energy consumption per project and per year, has drop from 2168 to 1344 MWh, this means an average decrease of 824 MWh/per year (−38%). This is equivalent to the electricity needed for a residential area of 78 families during one full year.

Impact on CO_2 emissions. To calculate the impact of savings in terms of CO_2 tones emitted into the atmosphere, it has been proceeded to use the information given in the projects themselves and when it has not been possible due to information lagging, it has been used the so-called "emission factor", which is a ratio that allows to transfer kWh savings into CO_2 tones equivalent (Minetur 2013). The emission factor established by the Spanish Ministry of Industry goes from 0.399 to 0.5 kg CO_2/kWh, depending on the source of energy used to produce electricity, and this leads to estimate an emissions savings value during the length (ten years average) of an average project between 3288 and 4120 tons of CO_2. The study's authors estimate that the projects included in the sample represent around 10% of the total Spanish ESCO projects during study timeframe, so it can be concluded that total savings potentially achievable with this type of energy efficiency projects, in terms of reduction of CO_2 emissions, could reach annually from 148,000 to 185,000 tons.

4 Conclusions

It is possible to conclude that Spanish ESCO projects provide cost savings (economics) and positive environmental effects to sustainability, in line with concept coined by Elkington (1998, 2004) and others. This sustainability is proven through strong energy saving results that, as average, represent yearly 38% less on energy consumption and huge amount of CO_2 tones not emitted to the atmosphere as pollution. From data is possible to infer that an average project could produce a saving during its life (10 years average) equivalent to the electricity needed for a small village of 780 inhabitants during a year.

Projects are manages both by large companies and SMEs, nevertheless large firms are more focused on public agreements than the others. Main reason could be linked to huge bureaucracy on public entities and in many cases waste time needed to understand complex procedures that has not been compensate through project financial payback. Within main applications it is very remarkable the importance of air-conditioning and lighting (mainly public street lighting) and this fit with studies in highly developed countries.

Regarding the third sustainability axis—social factors—authors could not go deeper to conclude in what extent such social factor is relevant and applicable in these projects in order to develop sustainability as defined in “triple bottom line” vision.

In opinion of the authors of this paper, ESCO business relationships have contributed significantly to improve the economic and environmental sustainability within Spanish companies that have implemented such type of projects, however it seems relevant to point out both the need for more publicity of projects results that stimulate the entrance of new players into these collaborative projects, and the need for new solutions search, both in the technological and organizational angles, to enable that such type of projects could continue providing incremental improvements in terms of sustainability, as still it has not reached the end of their potential improvement.

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Part VIII
Industry 4.0

Pushing the Limits of Lean Thinking–Design and Management of Complex Production Systems

Jochen Deuse, Christoph Heuser, Benedikt Konrad, David Lenze, Thomas Maschek, Mario Wiegand and Peter Willats

Abstract This paper presents an approach for handling variability in production systems. A classification for variability which includes a differentiation in non-value adding and value adding variability is proposed and indicators for their quantification are derived. It is shown that classical Lean methods fail in make-to-order production because of the misconceived influence of value adding variability. Consequently, different approaches from Data Mining and Factory Physics are applied.

Keywords Value adding variability · Dynamic value stream analysis · CONWIP based on set-up families · Workload control · Manufacturing data analytics

1 Introduction

In the light of globalized markets and growing competitive pressure, enterprises face the challenge to increase productivity and reduce costs. At the same time a high degree of flexibility to fulfil individual customer requirements is needed. This is particularly true for make-to-order (i.e. job shop) manufacturers.

In the context of series and mass production Lean methods have become prevalent for improving the efficiency and performance of production processes (Liker 2004), originating from the Toyota Production System (TPS). Particularly, automobile manufacturers and their suppliers take the TPS as a role model for their own production systems, but also companies in other industries have adopted Toyota's principles (Roth and Zur Steege 2014). Scientific studies pointed out that Toyota's tool box mainly aims at reducing variability in all operations as well as in the internal and external customer-supplier relationships (Gong et al. 2009; Spear and Bowen 1999). In this connection variability refers to product and process

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characteristics and is understood as the invisible main course of problems and dramatic losses in efficiency being inherent in all manufacturing processes.

The methods and principles of Lean Production are designed primarily to cater for the needs of series and mass production. Make-to-order manufacturers try to adapt them, but often fail due to product diversity and flexibility requirements. For such companies the proper handling of customer-induced variability, such as customer-defined delivery dates or customized product variants, may increase competitiveness and revenue. Consequently, the companies cannot merely copy Lean methods because eliminating all kinds of variability will also diminish adding value. To some extent, product and process related variability can be reduced economically reasonable. However, variability adding value for the customer has to be preserved and managed properly.

That is why a more sophisticated approach to handle and manage variability in the context of make-to-order production is required. To that end, this paper gives an overview on new approaches for the management of variability which take their special conditions and characteristics into consideration.

The remainder of this paper is arranged as follows: In Sect. 2 a new classification approach for variability is proposed providing a differentiated view on the various types of variability in manufacturing. On the basis of this classification, Sect. 3 presents criteria to describe and quantify variability in order to allow for the variability based analysis of a company's current condition. Sections 4 and 5 focus on variability induced limits of Lean methods as well as on new approaches for handling variability in make-to-order production. Finally, the paper is concluded in Sect. 6.

2 Classification Approach for Variability

Variability as a performance-defining factor of production has been widely discussed in the literature. However, a concrete and overarching distinction between value adding and non-value adding variability does not exist. As mentioned in Sect. 1, in the context of make-to-order production such a distinction is essential, because customer-induced variability may lead to a significant increase in customer value. For this reason, the Institute of Production Systems (IPS) has developed a classification approach for variability, differentiating between three classes:

1. Variability which must be eliminated: non-value adding
2. Variability which cannot be eliminated entirely: non-value adding
3. Variability which must not be reduced (directly): value adding.

The first variability class covers all of the well-known *muras*, causing fluctuations in performance and thus losses in productivity, product quality and ultimately customer satisfaction. Classical approaches of Lean Production can and should be used to eliminate all types of *muda*, i.e. this class of variability.

The second variability class, which may also be called "common cause variability", can only be reduced, but not be eliminated completely. It includes non-deterministic factors, such as environmental and weather influences, accidents or absence.

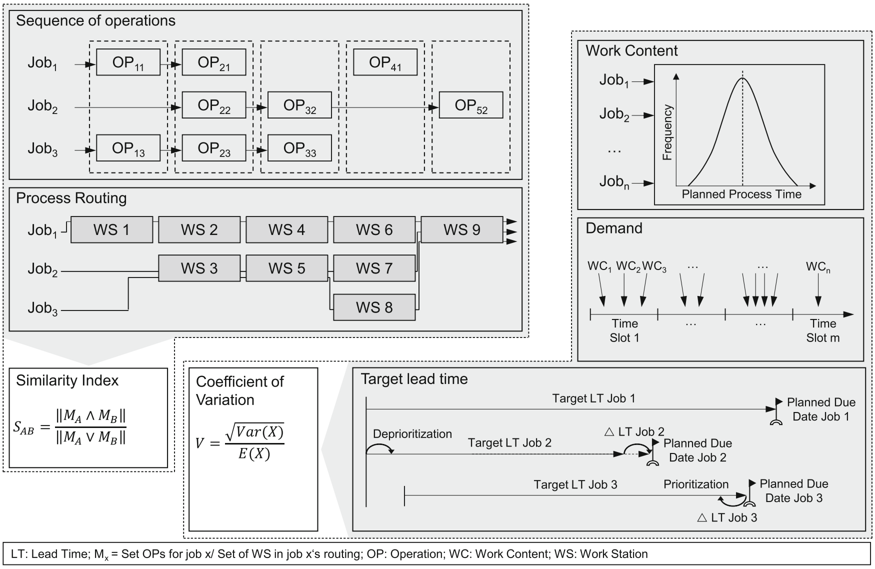
The third variability class represents the previously stated value adding variability. Since it represents customer benefits, it must not be reduced directly, but rather managed adequately. Examples for this class are respecting the customers' wishes, such as delivery dates, customized product variants or accepting rush orders. Although it creates additional value for the customer, it increases the production systems' complexity and thus costs and managing efforts. Consequently, the variability itself must not be reduced, but its impact on the production system should be, in order to achieve a profitable cost-benefit ratio.

3 Characteristics for VAV

In order to quantify value adding variability a more detailed breakdown of production systems' specific job and process properties is required. The following five criteria have been derived as measures for value adding variability (Fig. 1):

1. Variability of sequence of operations,
2. Variability of process routing,
3. Variability of work content,
4. Variability of target lead time and
5. Variability of demand.

Any of these variability classes should only occur if it adds value for the customer and otherwise be eliminated. Subsequently, the criteria are explained in more detail. *Variability of sequence of operations* describes the variation of job characteristics w.r.t. the specific sequence of operations actually carried out on them in the system. Operations are defined as work tasks to be executed and thus independent of specific machines/work stations used to do so. *Variability of process routing*, on the other hand, describes the variation of sequences of machines/work stations in the jobs' flows of material in a given period of time. It is thus relevant if specific operations can be carried out on more than one machine. *Variability of work content* describes the variation of planned process times of the jobs seen at one machine/work station in a given time span. *Variability of target lead time* describes the variation of lead times for all jobs seen in the system in a period of time set by production planning and control. Target lead times depend on customer requirements to be met to win orders as well as a company's prioritization policy concerning an order's profitability. *Variability of demand* describes the variation of the cumulated work contents of jobs arriving in different time slots. The higher the variation of demand the more likely the system will experience phases of over- or under-utilization.



$$S_{AB} = \frac{\|M_A \wedge M_B\|}{\|M_A \vee M_B\|}$$

$$V = \frac{\sqrt{Var(X)}}{E(X)}$$

Fig. 1 Variability criteria

In order to measure the different kinds of variability measurement parameters are required. Variability of sequence of operations and variability of process routing are multivariate and can be quantified with a similarity index. The authors propose to use an adapted Jaccard Index which allows a pairwise quantification of similarity of data points (Park and Suresh 2003). Variability of work content, target lead time and demand are univariate and can be measured employing coefficients of variation.

4 VAV Based Approaches for Make-to-Order Productions

It is perceived that in make-to-order productions variability in general is the predominant cause for complex planning and control processes as well as challenges in structured problem solving and process improvement routines. On the contrary, Lean Production offers a general approach on how to address such problems. It is widely accepted by both researchers and practitioners in the field of Industrial Engineering as its improvement potential to the aforementioned problem statements has been demonstrated and proven in various applications. Yet, these successful implementations focus on homogeneous, repetitive production scenarios, differing significantly in their characteristics from make-to-order productions. To capture the basic fundaments of a production system a classification approach is presented while new methods from Data Mining and Factory Physics are developed and applied.

Following Snowden's Cynefin framework (Snowden and Boone 2007), production systems can be categorized into ordered systems with static cause-effect relationships (simple and complicated systems) and unordered systems with dynamic cause-effect relationships (complex and chaotic systems) (Fig. 2). Simple and obvious production systems are usually in the focus of classic Lean Production approaches, which can easily be described with the first rule of Spear and Bowen (1999). "All work shall be highly specified as to content, sequence, timing and outcome". Those production systems are characterized by low VAV and cover simple, homogenous and repetitive assembly lines. Consequently, methods and tools like Value Stream Analysis (VSA) are used to analyze and visualize material as well as information flows (Rother and Shook 2003). Improvements derived by VSA often are buffer size reduction, process-synchronization, obeying customer Takt etc. (Richter and Deuse 2011).

However, as VSA only depicts a snapshot of the production system, it does not pose a suitable tool to access and optimize make-to-order production processes. Therefore, the advancement of VSA developed by the IPS is the *Dynamic Value Stream Analysis (DVSA)*, which considers the dynamic behavior of production systems. The DVSA does not just present a snapshot of the current state of a production system, but also captures its inherent variability by using several statistical measures and matrices. The different occurring sequences of operations, respectively process routings, are collected in matrices assigned to the different products. In contrast to the VSA, the fluctuations of demand, target lead time and work content are gathered by averages and complemented by measures of statistical dispersion like variance. The illustration is realized through a hierarchical dynamic simulation model. In a future step, the VAV criteria will be included in the analyses. Consequently, the DVSA will provide an in-depth view on the VAV in the analysed production system, combining the advantages of VSA, i.e. the easy-to-understand view of a production system with the detailed analyses of dynamic system behaviour.

Complicated production systems generally comprise make-to-order productions with a high amount of VAV. As a consequence, widely used pull-based Lean approaches, such as Kanban, fail to satisfy the second rule of Spear and Bowen (1999) ("Every customer-supplier connection must be direct, and there must be an unambiguous yes-or-no way to send requests and receive responses"). An approach to meet the requirements of complicated production systems of this class is *CONWIP based on set-up families*. This method combines CONWIP (Constant Work-in-Process) developed by Hopp and Spearman (2008) with a clustering approach from Data Mining. Clustering the product range results in product families with similar process routings and work content, which is a condition for the use of CONWIP. After clustering, CONWIP is applied.

As this approach already clusters product variants with a similar impact on production, it considers variability implicitly. However, for adding further value, the VAV criteria will be applied and thus pose the basis of the clustering process, depending on the grouping criteria. For example, if demand fluctuations shall be compensated, the respective criterion will be the target value of the clustering process, in this case with the target to reduce its inner-cluster coefficient of variation.

The third rule of Spear and Bowen (1999), “The pathway for every product and service must be simple and direct”, cannot be fulfilled in complicated production systems with a very high amount of VAV. However, an approach from Factory Physics to meet their individual requirements is *Workload Control (WLC)*, which does not need similar process routings and work content. With WLC the work order load of a production unit is controlled so that (according to Littles Law) cycle time is proportional to WIP. Furthermore, the work order release is WIP-related, which results in parallel arrival and departure curves of the controlled production unit.

Since WLC is a decentralized production control approach, it is well suited for make-to-order productions. However, decisions on dispatching orders are only based on the respective workload which, on occasion, might not be the right approach to increase added value. By continuously calculating the VAV criteria throughout the entire production process, retrospective analyses and, on this basis, prospective decisions on the best order dispatching can be inferred.

Complex production systems, however, are characterized by a high amount of VAV and complex cause-and-effect relations. Productions like the fully automated machining of engine components are covered by this class. The fulfillment of the fourth rule of Spear and Bowen (1999), “Any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level in the organization”, can hardly be ensured. Single factor experiments which are most commonly used to initiate improvement processes in classical Lean Production (Maschek et al. 2011), are not suitable for complex production systems. However, using *Manufacturing Data Analytics*, which is an application of different supervised and unsupervised Data Mining algorithms for discovering multivariate connections and patterns in manufacturing data, an eligible alternative to single factor experiments is provided. Through the growth of knowledge about the systems’ behavior expedient system adjustments can be made to raise its productivity.

To make the decisions even more reliable concerning the physical production system, the future analyses will be targeted on specific and value adding variables, defined by the VAV criteria. Finally, the analyses will be focused on improving value adding characteristics, rather than providing a more holistic production analytics approach.

Ultimately, chaotic systems are characterized by chaotic processes and the absence of manageable patterns which cannot be found in production systems and thus are not analyzed in this paper.

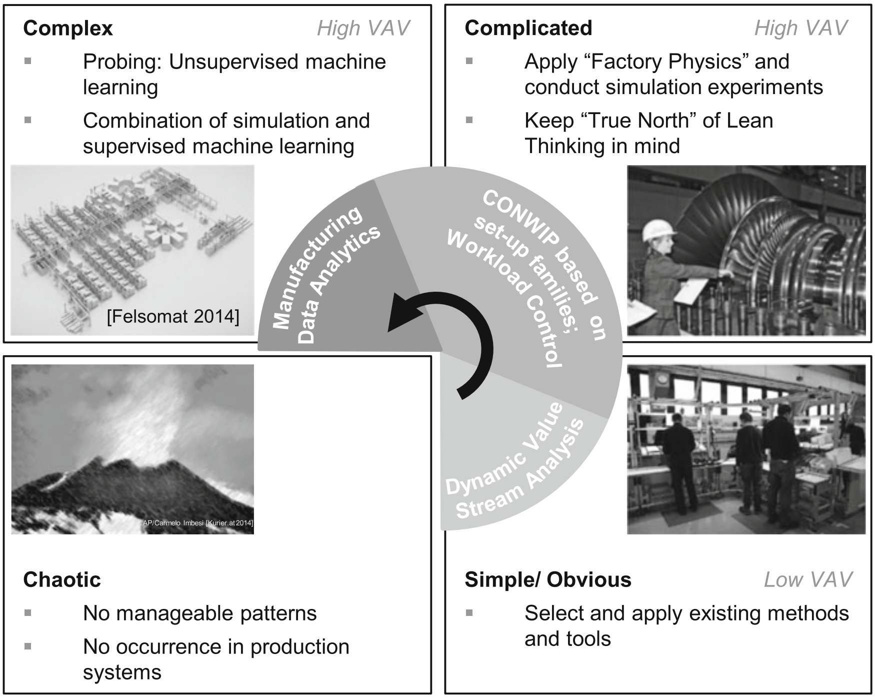


Fig. 2 Classification approach for production systems (acc. to) Snowden and Boone (2007)

5 Conclusion and Outlook

In the past, variability has been considered as the "universal enemy" and thus was reduced and eliminated (Maschek et al. 2011), regardless of its impact on production. Consequently, production systems had not been classified concerning their individual variability characteristics, particularly with regard to value adding and non-value adding classes. Furthermore, the presented rules of Spear and Bowen (1999) imply to be universally valid in the way they are. However, the underlying assumption of low variability, especially value adding variability, limits their applicability to homogeneous, repetitive production and therefore prevents a direct transfer to highly variable scenarios, e.g. make-to-order production.

With the presented definition and characterization of criteria for value adding variability, limits of traditional Lean Production approaches in make-to-order production systems can be overcome. New tools, such as a dynamic value stream analysis, CONWIP based on set-up families or Manufacturing Data Analytics, provide an approach to manage value adding variability in production systems, especially beyond TPS, efficiently. Various field experiments have proven their effectiveness and the widespread application and implementation will be continued in future research and industrial projects.

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Industry 4.0: A Classification Scheme

David Pérez Perales, Faustino Alarcón Valero and Andrés Boza García

Abstract One of the most novel concepts that has been applied to companies in recent years is "Industry 4.0". This is a wide term that implies a drastic change in the way companies operate. This paper reviews some of its existing literature in order to give an accurate definition of such a concept. A classification scheme based in two main pillars, on one hand the features which characterize that term and on the other hand the technologies and concepts that support their development is also defined. All results are based on a structured literature review.

Keywords Industry 4.0 · Cyber-physical systems · Internet of things

1 Introduction

Important advances in manufacturing technologies and communication, computing and information systems within recent years are enabling new ways to perform operations in industrial and service sectors.

This new paradigm is called "Industry 4.0" (term coined by "Industrie 4.0 Working Group and the "Plattform Industrie 4.0") and seems to mark the future roadmap, leading to the fourth industrial revolution (Erol et al. 2016).

Industry 4.0 promotes, among other things, autonomous decision-making, interoperability, agility, flexibility, efficiency and cost reductions.

This is the reason by which many companies are aiming to implement the technologies and concepts related to "Industry 4.0".

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However, current research about "Industry 4.0" is diverse, limited and clearly insufficient regarding its implementation in operational levels of the production processes (Herman et al. 2015).

This lack of roadmaps and guides supporting its implementation, as well as its high complexity makes "Industry 4.0" too uncertain (Erol et al. 2016). Moreover, they are discouraging the early, orderly and effective implementation of the concept.

In addition to that, the many contributions of research centers, companies, universities and professionals are making the term "Industry 4.0" even more confuse.

Even the key promoters of the idea only describe the vision, the basic technologies the idea aims at, and selected scenarios but don't provide a clear definition. As a result, a generally accepted definition of Industry 4.0 has not been published so far (Herman et al. 2015).

Maybe, one of the underlying causes is that too many different technologies and concepts are grouped under the wide term "Industry 4.0", as it is stated by Herman et al. (2015): "*Industrie 4.0 is a collective term for technologies and concepts of value chain organization*".

This paper aims to collect and organize all the relevant terms related to "Industry 4.0" in order to facilitate its implementation by different users such as companies, technologists, computer engineers and final users.

The paper is structured as follows: In Chap. 2 a brief summary of the literature review is presented. Then, in Chap. 3, a classification scheme is proposed. Finally, in Chap. 4 some conclusions are drawn.

2 Literature Review

First, a list of different characteristic features of "Industry 4.0" as well as different technologies and concepts which support that term were determined based on the frequency they were quoted in the literature review, composed by twelve main papers (Anon 2014; Herman et al. 2015; Lasi et al. 2014; Schlechtendahl et al. 2014; Lee et al. 2015; Shrouf et al. 2014; Atzori et al. 2010; Miorandi et al. 2012; Herčko et al. 2015; Pfohl et al. 2015; Stiel and Teuteberg 2015; Erol et al. 2016), selected from the initial search results.

Then, all the former papers were contrasted with other ones which aimed to propose classification schemes, as the ones of Herman et al. (2015) and Pfohl et al. (2015). This allowed to analyze in which extent the different features and technologies/concepts were taken into account and organized.

3 Proposed Classification Scheme

From the previous analysis, a classification scheme was proposed, leading to a better understanding of the concept “Industry 4.0”.

This classification scheme is based on two pillars: the features that characterize such a concept and the technologies or concepts that support them. Besides, the technologies or concepts that enable the development of the former individual features are also pointed out.

As a result, eight characterizing features were selected as the most representative ones, although a few other ones encountered in the literature were also added if they matched them. Their description is as follows:

1. **Virtualization**: means that companies are able to monitor physical processes. These sensor data are linked to virtual plant models and simulation models. Thus, a virtual copy of the physical world is created (Herman et al. 2015). Another close feature is digitalization.
2. **Interoperability**: means that all the systems, in and out the company are connected. Standards are a key success factor for communication (Herman et al. 2015). Other close features are socialization or network collaboration.
3. **Autonomization**: “Industry 4.0” technologies and concepts are enabling machines and algorithms of future companies to make decisions and perform learning-activities autonomously. This autonomous decision-making and learning is based on man-made algorithms and enables whole factories and manufacturing facilities to work with minimum human-machine interaction (Pfohl et al. 2015). Another close feature is decentralization.
4. **Real-time availability**: for organizational tasks it is necessary that data is collected and analyzed in real time. So, the status of the plant is permanently tracked and analyzed (Herman et al. 2015). Other close features are remote monitoring and mobility.
5. **Flexibility**: due to new and more complex demands requirements, processes such as products development, products production processes or decision making procedures need to be performed faster (Lasi et al. 2014). Another close feature is mass-customization.
6. **Service Orientation**: the services of companies over Internet can be utilized by other participants. They can be offered both internally and across company borders (Herman et al. 2015).
7. **Energy efficiency**: climate change and scarcity of resources are megatrends that will affect to future industry players. These megatrends leverage energy decentralization for plants, triggering the need for the use of carbon-neutral technologies in manufacturing. Using renewable energies will be more financially attractive for companies (Anon 2014).

Secondly, a list of different technologies and concepts that support the future development of the concept of “Industry 4.0” was also considered.

For this purpose, a two-step approach was applied. In the first step, a list of technologies and concepts were extracted from the literature review. This list was too long, so it was attempted to reduce its complexity. For that, in the second step, four technologies/concepts that had the highest relevance and the widest scope were selected forming four groups: cyber-physical systems, Internet of Things/Services, Smart Data and Smart Factory. The remaining ones were then allocated in each of them. It is important to remark that the selected technologies/concepts overlap so that some concepts could have been allocated in different groups. In this work just the most representative one was chosen to allocate them.

In the following, the 4 selected technologies/concepts are reflected and described, jointly with those technologies/concepts related to them (Tables 1, 2, 3 and 4).

1. **Cyber-Physical Systems (CPS)**: is defined as transformative technologies for managing interconnected systems between its physical assets and computational capabilities. By integrating CPS with production, logistics and services in the current industrial practices, it would transform today's factories into an Industry 4.0 factory with significant economic potential (Lee et al. 2015).

Table 1 Technologies/concepts related to CPS

Cyber-Physical Systems (CPS):
M2M, embedded systems, miniaturization of electronics, distributed and interconnected production facilities, Mobile Computing, Communication Interfaces, Information Server, Manufacturing Execution Systems (MES), Monitoring Application, Multidimensional data correlation, Smart analytics, identification and memory, Clustering for similarity in data mining, Integrated simulation and synthesis, Remote visualization for human, consistent digitization, Internet protocol, Interconnected Plants, standards for data transfer, standards in security procedures, cyber security, telecommunications and the cloud, software programming, data analysis, scientific computing

Table 2 Technologies/concepts related to IoT/IoS

Internet of Things/Services (IoT/IoS):
Sensors, RFID, mobile technologies, Zero-defects sensors, Reactivity sensors, Traceability sensors, Predictability sensors, mobile services and technolgies, actuators, smart phones, standardized software, hardware interfaces, Apps, Web 2.0, smart objects, smart networks, data acquisition systems, connecting the machines and equipment to suppliers, IT systems, Smart Robots, smart sensored human-machine interfaces, Internet-connected devices, Ubiquitous computing, network of devices, ICT, human-computer cooperation, Social media, crowdsourcing, Networking and communication, e-commerce, e-government

Table 3 Technologies/concepts related to Smart Data

Smart Data:
Cloud computing, big data, storing and analyzing data, position and status of an object (traceability), position or condition of a tool, electronic documents, drawings, simulation models, production status, energy consumption behavior, material movements, customer orders and feedback suppliers' data, sensor data

Table 4 Technologies/concepts related with Smart Factory

Smart Factory:
Smart Product, Smart Logistics, Smart Machines, Smart Devices, Smart Manufacturing Processes, Smart Engineering, Manufacturing IT, Continuous Innovation, Modularization of processes and products, Calm-systems, resilient and self-adaptable machines, decentralized intelligence, self-optimization and reconfiguration machines, automatic solutions, versatile operations, autonomous manufacturing cells, efficient manufacturing, adjusted production schedules, optimized capacity, carbon-neutral technologies in manufacturing, renewable energies, generate own power, 3D visualization, 4.0 supplier network, 3D-printing, autonomous vehicle, small and autonomous manufacturing cells, fragmentation of the value chain, new business models, design thinking, continuous training and development in the workplace, collaborative and cross-cultural competencies, standardization, interdisciplinary skills, analytics specialists, engineers and programmers, data scientist, cyber safety guards, highly interactive, socio-technical systems, intelligently networked objects in manufacturing, technological innovations, new knowledge and capabilities, new principles of work and leadership, demography-resistant work design, dynamic production networks, energy and resource efficiency, increased productivity, horizontal and vertical integration through value networks, end-to-end digital integration of engineering, Business 4.0, e-Residency, fractal company, self-similarity, self-organization, self-optimization, goal-orientation, adaptable manufacturing organizations, cross–company information interfaces, form structures of high internal interaction and exchange of resources, green transport corridors, self-organizing, adaptive logistics, customer integrated engineering, SC-based Business Models, open Innovation Models, Service Design Models, complex and intertwined manufacturing networks, fragmentation of the value chain, cross–company information interfaces, sustainability aspects, transparency and traceability of the products during life-cycle, sustainable product design

2. **Internet of Things/Services (IoT/IoS)**: IoT is a system a system where the physical items are enriched with embedded electronics (RFId tags, sensors…) and connected to the Internet. Thanks to IoT physical objects are seamlessly integrated into the information network where they can become active participants in business processes; communicate information about their status, surrounding environment, production processes, maintenance schedule and even more (Shrouf et al. 2014). IoS enables service vendors to offer their services via the internet. It consists of participants, an infrastructure for services, business models and the services themselves (Herman et al. 2015).
3. **Smart Data**: data is often referred to as the raw material of the 21st century. Indeed, the amount of data available to businesses is expected to double every 1.2 years. A plant of the future will be producing a huge amount of data that needs to be saved, processed and intelligently analyzed. Innovative methods to handle big data and to tap the potential of cloud computing will create new ways to leverage information (Anon 2014).
4. **Smart Factory**: it gives an overview of the firm as an interconnected global system on a microeconomic level. Outside the factory a 4.0 supplier network, resources of the future, new customer demands and the means to meet them are seen. Inside the factory, new production technologies, new materials and new ways of storing, processing and sharing data are envisioned (Anon 2014).

Finally, the proposed classification scheme aims to understand the relevance of the many interrelated technologies/concepts with respect to the achievement of the aforementioned "Industry 4.0" characterizing features.

For that, from the selected papers from the literature review, was analyzed how the different technologies/concepts were related to those features. Base on that, the contribution of all of them was individually collected and analyzed whether or not they enabled the virtualization, interoperability, autonomization, real-time availability, flexibility, service orientation and energy efficiency features.

Table 5 shows the contribution of the different relevant technologies/concepts to the development of the features characterizing the "Industry 4.0".

Due to space restrictions, only the most contributing technologies/concepts of each group (in bold in Tables 1, 2, 3 and 4) are briefly explained in the following:

1. **CPS**

- M2M: it is a broad label that can be used to describe any technology that enables networked devices to exchange information and perform actions without the manual assistance of humans. M2M communication is often used for remote monitoring.

2. **IoT/IoS**

- Sensors: it is a device that detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena. The output is generally a signal that is converted to human-readable display at the sensor location or transmitted electronically over a network for reading or further processing.
- RFID: it is a technology that incorporates the use of electromagnetic or electrostatic coupling in the radio frequency (RF) portion of the electromagnetic spectrum to uniquely identify an object, animal, or person. It is coming into increasing use in industry as an alternative to the bar code. The advantage of this technology is that it does not require direct contact or line-of-sight scanning.

Table 5 Contribution of the different relevant technologies/concepts to the development of the features characterizing the "Industry 4.0"

Features/relevant concepts	CPS	IoT/IoS	Smart data	Smart factory
Virtualization	X	X		X
Interoperability	X			X
Autonomization	X	X		X
Real time availability		X	X	X
Flexibility				X
Service orientation		X	X	X
Energy efficiency				X

3. **Smart Data**

   - Cloud Computing: it is a general term for the delivery of hosted services over the Internet. It enables companies to consume compute resources as a utility rather than having to build and maintain computing infrastructures in-house. It promises several attractive benefits for businesses and end users.

4. **Smart Factory**

   - Smart Products: they are specializations of hybrid products with physical realizations of product categories and digital product descriptions that provide the following characteristics: personalized, adaptive, pro-active, business aware, location aware and network capable. Since smart products combine a physical product with additional services, they are a form of product service system.

4 Conclusions

Based on a structured literature review, the meaning of the so-popular and at the same time so wide concept "Industry 4.0" was understood. This was performed by proposing a classification scheme made up of two main inputs.

On one hand analyzing which features may better characterize the term "Industry 4.0". It was stated that the main features were virtualization, interoperability, autonomization, real-time availability, flexibility, service orientation and energy efficiency. On the other hand analyzing which technologies and concepts may be classified under the term "Industry 4.0". Many technologies and concepts were analyzed within the literature, grouping them into 4 relevant and representative ones: Cyber-Physical Systems (CPS), Internet of Things/Services (IoT/IoS), Smart Data, Smart Factory. Finally, it was stated how these technologies and concepts individually contributed to enable the achievement of the aforementioned characterizing features.

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Framework for a New Wave of IT-Enabled Business Process Transformations

Miguel Gutierrez and Francisco Sastron

Abstract Consolidation of disruptive techonologies such as 3D printing, Big Data, Cloud Computing, the Internet of Things and Cyber-Physical Systems have led to the advent of the Industry 4.0 revolution. As a consequence, a new wave of automation and IT-enabled process transformations is coming. We find Business Process Reengineering/Redesign (BPR) remaining as a conceptual reference for fundamental rethinking and redesign of business processes. Stemming from the identification of the insufficiencies of reference frameworks to characterize the different types of business process changes, we propose a new conceptual framework: the IT-Enabled Business Process Transformation Matrix. The horizontal axis of the matrix represents the scope of the change, whereas the vertical axis represents the degree of transformation. Some examples illustrate its practical interest and flexibility to incorporate a great variety of process transformations based on technological innovations.

Keywords Business process transformation · Business process rengineering/redesign · Industry 4.0 · Information technology

1 Introduction

Consolidation of disruptive techonologies such as 3D printing (additive manufacturing), Big Data, Cloud Computing and the Internet of Things led to the announcement of a new industrial revolution at the beginning of this decade

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(Markillie 2012). Artificial Intelligence is spreading under the “smart movement” (smart buildings, smart cities, smart factories). Concepts evolve rapidly as the industry and experts are becoming aware of the vast possibilities offered by these technologies (Höller et al. 2014). The conceptualizations of Cyber-Physical Systems along with the Internet of Things and Cloud Computing have led to the eclosion of the Industry 4.0 (Schuh et al. 2015, Schwab 2016).

With the advent of a new technological era, there is a need for a practical framework to characterize the new wave of process transformations enabled by the new technologies. Regarding IT-enabled process transformations, we find that the essence of BPR (Business Process Reengineering/Redesign) remains as a conceptual reference.

The origin of BPR traces back to the summer of 1990, when the publication of two papers—one by Davenport and Short (1990) and the other by Hammer (1990)—initiated a revolution in business process management. Both papers presented a new paradigm of business process transformation, characterized by the key role of Information Technologies (IT) as enabler of the process change, the emphasis on cross-functional processes as the drivers of the enterprise, and the need to rethink the business processes and transform them in the light of the possibilities offered by the new technologies. This new paradigm spread rapidly under the acronym BPR (Business Process Reengineering/Redesign).

During the first years after its irruption, BPR had a huge impact both in the academic and professional communities that came along with a wave of expert criticisms as well as valuable feedback from real experiences. Ten years after the publication of the seminal works, the interest in BPR diminished and led way to other concepts such as BPM (Business Process Management) (Van der Aalst, Hofstede and Weske 2003).

Yet, instead of vanishing as some authors anticipated, BPR remained as an applicable concept. Even more, it received a new peak of attention almost 20 years after its appearance. Despite the controversy, the essence of BPR holds its interest as a reference paradigm: “Although overhyped, sharply criticised, and rebranded repeatedly over the past 15 years, business processes redesign (BPR) has remained on the agenda of many organisations […] it is more than probable that the interest for what is the essence of BPR, inventing new processes to do business, will rise again in the coming years” (Mansar and Reijers 2005).

In order to develop a practical framework aimed at characterizing the new wave of process transformations that are to take place under the forthcoming industrial revolution, we review the classic reference frameworks taken mainly from the BPR related literature and, after analyzing their insufficiencies, we then propose a new IT-enabled business process transformation framework.

2 Reference Frameworks

As a consequence of the tremendous expansion of BPR in the first years and the aforementioned wave of expert criticisms and valuable feedback from real experiences, BPR developed turbulently on a trial-and-error basis, which caused confusion and prevented this paradigm from receiving a precise conceptual treatment (Kettinger, Teng and Guha 1997). Even Davenport and Hammer developed their initial proposals and diverged and disagreed in some aspects. To face this situation, some authors aimed at clarifying the concepts involved in BPR projects and proposed different conceptual frameworks, particularly in the 90s. We will focus on those trying to organize IT-enabled business process changes based on the radicality of the approach and the business area in which they take place.

Since Hammer opposes process reengineering to automation ("Do not automate, obliterate") and process-oriented versus functional organizations (Hammer 1990), automation is frequently identified with an intra-functional transformation whereas reengineering is identified with an inter-functional transformation. Usually, reengineering considers a few basic business processes that involve and cross all the main functional areas of the company in order to satisfy the customer needs. Natural extension according to this notion is to consider the processes that involve all the supply chain companies (Short and Venkatraman 1992; Gunasekaran and Nath 1997). This is, to observe material and information flows throughout the network of suppliers, producers and distributors; a vision that emerges and consolidates further than the reengineering scope, until becoming essential in the field of business management (Cooper, Lambert and Pagh 1997).

This progression in the scope of IT-enabled business transformation reflects in the framework proposed by Venkatraman (Fig. 1). It is a remarkable and highly

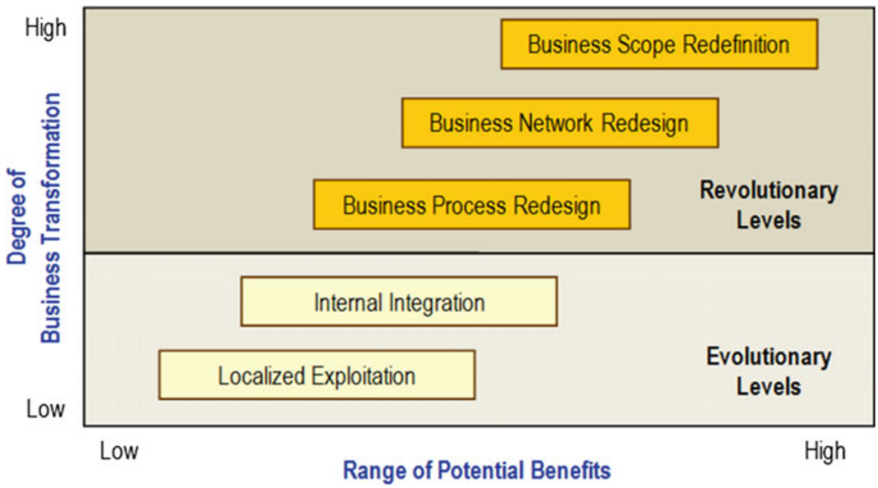

Fig. 1 Five levels of IT-enabled business transformation (Venkatraman 1994)

acknowledged framework, in which the author relates the degree of business transformation versus the range of potential benefits. Hence, he finds five IT-enabled business transformation levels (Venkatraman 1994):

1. Localized Exploitation: Refers to the deployment of a specialized IT application for a specific functional area; for example, a 24/7 customer support service.
2. Internal Integration: It is the logical extension of the first, attempting to leverage IT capabilities throughout the entire business process. This level deals with two necessary types of integration: technical interconnectivity of different systems through a common IT platform, and business process interdependence across different functional areas. It involves automation with a process oriented inter-functional view, but without significant process transformation.
3. Business Process Redesign: Relates to the BPR concept, which implies a fundamental rethinking of the basic business processes and with IT capabilities playing a central role.
4. Business Network Redesign: Goes beyond the boundaries of the organization and represents the redesign of the nature of exchange among multiple participants in a business network through effective deployment of IT capabilities.
5. Business Scope Definition. Indicates a transformation at the highest strategic level, addressing the question “What role—if any—does IT play in influencing business scope and the logic of business relationships within the extended business network?”

Albeit the undoubt interest of Venkatraman’s framework, it is based on an intrinsic hypothesis that limits its range of applications: the shifts in the scope of the transformation take place along with shifts in the degree of transformation. From level 2 to level 3, not only varies the fact that the scope goes from a single process to the key business processes of the enterprise, but the type of transformation, which in level 2 is more integration-oriented whereas in level 3 reflects BPR rethinking and redesign. That shift distinguishes the evolutionary levels from the revolutionary levels. In turn, transition from level 3 to level 4 represents the aforementioned natural extension to the supply chain.

Therefore, according to Venkatraman’s framework it would make no sense to attempt a transformation initiative in a localized functional subarea with an integrationist view and that would imply a radical redesign of the processes belonging to that area. Likewise, it would not either make sense to attempt the automation of a process that would involve different supply chain enterprises.

This linkage between the scope and the degree of process transformation can be found in multiple references. It is worth noting the work of Kettinger, Teng and Guha (1997) in which the authors, after a thorough analysis of BPR tools and methodologies, propose a worksheet aimed at helping in defining the appropriate degree of radicality when planning a process transformation. The worksheet relates the degree of transformation—conceived as a continuous axis that splits in three major areas (process improvement, process redesign, radical reengineering)—with 11 contingency factors to consider in a BPR initiative. The contingency factors are valued from 1 to 5, and there is a biunique relation between that values and the degree of transformation axis. One of the factors to consider is the scope of the transformation, ranging from intra-functional (value 1) to interorganizational (value 5). Hence, again the scope and degree of transformation go hand in hand.

The conceptual key to break this biunique relation is the scale factor, for which Edwards and Peppard (1994) give a valuable and suitable explanation:

> A key issue often debated is whether or not processes must cross functional boundaries for the redesign initiative to be classified as BPR. We believe this to be problematic and that this distinction is artificial. It depends on how functions are defined within an organization. More importantly, we're not sure it matters. We find that it is more fruitful to examine the level of granularity at which the redesign is taking place. BPR can be conducted at the highest level in an organization with the organization itself considered as a process which converts capital, labour, information and energy into certain outputs […] (This process) is then operationalized at a lower level in terms of the processes that cross functional boundaries that are critical to meeting business objectives. These processes can be further subdivided into subprocesses some of which may be totally within a single function. Some refer to these subprocesses as tasks or activities or procedures. Alternatively, these single-function subprocesses could be considered as processes in their own right which cross subboundaries within the function. Hence, one organization's that does not cross functional boundaries is another's process that does cross subboundaries: it all depends upon the level of granularity that is employed when undertaking the analysis […] Yet it is possible to take any process in isolation and redesign it […] Is not BNR (business network redesign) an example of BPR at a high level of granularity with organizations undertaking joint BPR?

As Edwards and Peppard question in the last quoted sentence, Business Network Redesign, which corresponds to Venkatraman's level 4, can be conceptualized as an example of large scale BPR. But the scale change only implies varying the BPR target system, not an alteration of the degree of transformation.

With regard to Venkatraman's framework, Edwards and Peppard underline the interest of introducing risk as a factor to consider; in the sense that a raise in the degree of transformation not only leads to a raise in the potential benefits, but also in the level of risk. It is a consideration coherent with the aforementioned worksheet of Kettinger, Teng and Guha (1997) as well as with the study of Fiedler, Grover y Teng (1994). These authors analyse 59 IT-enabled process transformations, but, as a distinctive feature, they break the linkage between the scope and the degree of transformation, defining two possibilities for both. Thus, they analyze the four possible combinations of automation and reengineering on the one hand and intra-functional and inter-functional on the other. Results show that the lowest expected risk and benefits occur when an intra-functional automation is accomplished, whereas, correspondingly, highest risks and benefits are to be expected in reengineering initiatives crossing functional boundaries. The other two possible combinations, intrafunctional reengineering and interfunctional automation present moderate levels of expected risks and benefits.

3 IT-Enabled Business Process Transformation Matrix

Taking as a ground the described frameworks as well as other similar works and aiming at overcoming their limitations, we develop a practical reference framework intended to characterize the variety of IT-enabled business process transformations. Our proposal materializes in the matrix of Fig. 2, in which the internal rectangles show different process transformation examples.

Horizontal dimension of the matrix corresponds to the scale factor underlined by Edwards and Peppard as essential. It represents the scope of the transformation, distinguishing four basic areas that can be extended as needed. The basic areas determine if the transformation crosses the functional boundaries of, respectively, the supply chain, the main enterprise functions, the functional subareas inside each main function, and so on. In a big company, it will be necessary to continue with the functional subdivision. When a specific case is to be defined, it is highly recommendable to modify the generic titles of the horizontal dimension so as they become illustrative. Finally, the scope of the transformation inside a functional division is represented by varying the size of the rectangle.

Vertical dimension of the matrix represents the degree of process transformation in relation to the scale at which the transformation takes place, i.e. making a comparison with how the process (or subprocess) is done prior to the change. As a reference, the matrix distinguishes three basic zones, although it is important to note that, conceptually, it is a continuous dimension. Automation corresponds to the classic concept of a process improvement achieved by the implementation of a new technology; Non-Radical Redesign refers to a new way of accomplishing the process according to the possibilities of a new technology, but taking the previous process design as starting point and preserving its basic dynamics; Reengineering implies the radical redesign of a process fostered by a new technology.

Three illustrative examples of the proposed approach are depicted in Fig. 2. It is noteworthy that it would be difficult to characterize them in a unique framework with the traditional approaches.

- Case A. An industrial company agrees with its main suppliers to automate the purchasing process. The transformation crosses the boundaries of the enterprise since it takes place in the scope of the supply chain. It is an automation of the process in order to carry it out in a similar way than it has been done, but taking advantage of executing it electronically. Consequently, it is positioned in the lower part of the matrix (see Fig. 2). Finally, the transformation only involves one subprocess so it is represented as a small rectangle.
- Case B. An industrial company has decided to implement RFID tags for materials tracking. To take advantage of its potential, along with incorporation of the new technology, the company will redesign the processes related with the flow of materials through the shop, warehouses and distribution, though keeping the basic transformation and distribution processes. It is not only an automation, since the

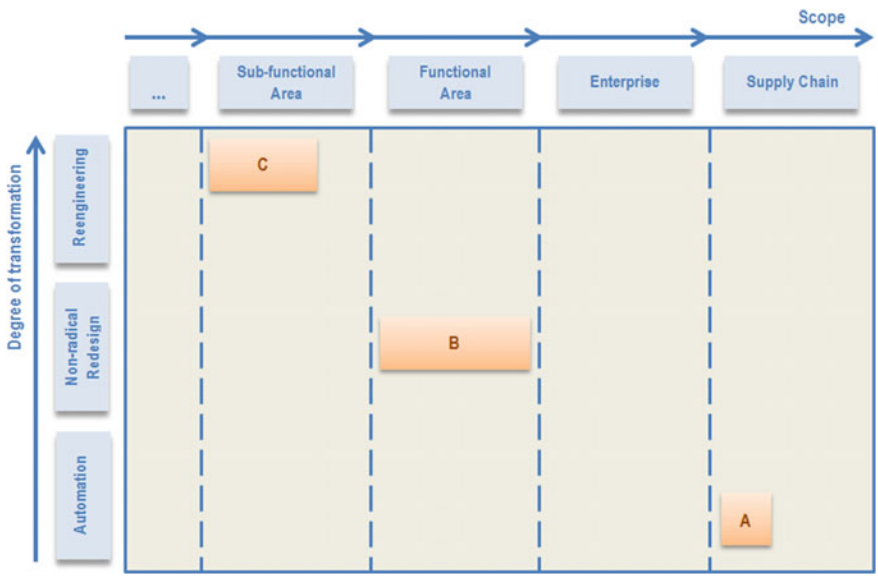

Fig. 2 IT-enabled business process transformation matrix

new technology implies the redesign of many interrelated subprocesses of the operations department, including planning and control. All the *Operations function* will be involved, which is represented by the rectangle covering the whole area (see Fig. 2).

- Case C. An industrial company has decided to renew completely one of its warehouse areas, the one keeping higher turnover products, which is transforming into a sophisticated fully-automated warehouse. The new warehouse will allow big efficiency improvements through the drastic reduction of non-value adding activities. It implies radically transforming all the warehouse material handling processes, so the rectangle is positioned about the upper part of the matrix (see Fig. 2). The change affects the rest of warehousing areas, but only with respect to the interference with the new automated area. Therefore, the transformation involves much part of the *warehousing sub-functional area*, belonging to the *Operations function* (note that it would be advisable to specify these denominations in the matrix, for the sake of better understanding).

4 Conclusions

Technologies such as 3D printing, Big Data, Cloud Computing, the Internet of Things and the eclosion of Cyber-physical systems that have led to the advent of the Industry 4.0 revolution, bring a new wave of automation and IT-enabled process transformations. Therefore, there is a need for a practical framework to characterize these initiatives.

Classic reference frameworks from BPR-related literature lack flexibility to cover many practical cases. The key to find a satisfactory solution stems from treating independently the scope of the transformation and the degree of the transformation. Thus, we construct a matrix from these two dimensions called the IT-Enabled Business Process Transformation Matrix. Some illustrative examples underline its applicability and show its capability to characterize a variety of process transformations ranging from pure automations to radical redesigns, and from a localized subfunctional unit to the entire supply chain. Future works include characterizing a representative number of cases taken from the literature and identify best practices and critical factors in BPR initiatives so the Matrix can be used not only as a descriptive tool but also as a prescriptive tool.

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Part IX
Education

Development of a Lean Assessment Tool for Small and Medium Sized-Enterprises

Amine Belhadi, Fatima Ezzahra Touriki and Said El fezazi

Abstract Despite the existence of a wide variety of measures for numerous aspects of lean production in the literature, many researches and studies have proved that the use of measures in lean implementation in SMEs (small to medium sized enterprises) is very limited. The main reason behind this situation is that most of these measures are designed and tested in large companies without any focus on SMEs. Moreover, SMEs cannot imitate in total the models developed for large enterprises. In this scheme, the present paper aims at developing a new tool adapted to SMEs for lean assessment. The aim of this tool is to provide an effective measure of the leanness level of SMEs in order to drive efforts towards the achievement of lean transformation. Compared to existing lean measures, the proposed tool is simple with a minimum number of indicators that are confirmed as suitable to SMEs. Through the proposed tool, SMEs will be able to define easily and effectively "how lean they are" in order to focus lean change efforts.

Keywords Lean production · Small to medium-sized enterprises · Performance measurement system · Leanness measurement

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1 Introduction

Lean production is one of the most widespread performance enhancement approaches. Since its appearance in the early 1990s, this approach has shown a great capacity to improve companies' competiveness (Sánchez and Pérez 2001). The central aim of lean production is to create a streamlined system intended to deliver high-quality products at the pace of customer demand using minimum of resources (Shah and Ward 2003). As a matter of fact, many companies, of all types and sizes, have been trying to adopt lean in order to keep competitive in an increasingly global market (Anand and Kodali 2008).

As for Small and Medium-sized Enterprises (SMEs) the challenge is even greater, since the sustenance of most national economies relies heavily on the survival and the development of these companies (Shah and Shrivastava 2013; Achanga et al. 2006). Therefore many SMEs have become attracted by lean especially with its proven success in large companies. A backbone in successfully implementing lean production in SMEs is being able to effectively measure and monitor organization's "leanness level" in order to benchmark its performance with its objectives and the competitors (Shah and Shrivastava 2013). For this reason, Performance Measurement Systems (PMS) has been attracting increasing attention and becoming one of the important key for every business organization. However, PMS in SMEs has not received sufficient focus. Most of the existing studies in the literature addressing the topic of lean implementation in SMEs focus on 'how to become leaner', but very little researches have been carried out to 'how lean it is' (Garengo 2009; Cocca and Alberti 2010).

The present research is intended to propose an integrated tool of lean assessment suitable to be applied in SMEs. This tool is developed through the combination of both qualitative and quantitative lean implementation progress in the organization. This powerful tool provides for SMEs a basis for enhancing their decision-making processes and redirecting their efforts toward lean production.

The paper is arranged as follows: After the introduction, Sect. 2 describes the research objectives and methodology. Afterwards, different steps of the development of the tool are shown in Sect. 3. Finally, conclusions are included.

2 Objectives and Methodology

2.1 Problem Definition and Research Objectives

The importance for all organizations—be it small or medium or large scale enterprises- of evaluating and modifying their performance while introducing lean production is well documented in the literature (Cocca and Alberti 2010). For this reason, many authors have provided a large number of models, indicators and tools for performance and change assessment. However, SMEs are still behaving in a reactive manner and therefore, relaying on a short term vision (Garengo and Bernardi 2007). This is due, according to several authors, to the lack of a simple and adapted method of assessing changes toward lean production that is believed to be perfectly suitable for SMEs. In fact, all the frameworks for lean assessment provided by the literature, have been earmarked for, and confirmed in, large companies (Cocca and Alberti 2010; Hudson et al. 2001).

For these reasons, there is a real need for developing a new method for SMEs by adapting the existing models designed for large company with SMEs characteristics. This method must provide a more comprehensive, simple and not resources consumer way to support SMEs efforts toward lean production. With this view, the present paper provides an assessment tool that SMEs can use to evaluate systematically the effectiveness of their transformation and take in time corrective measures. To fulfill this aim, three objectives are developed for this research: (1) to identify the most common indicators of assessment in the literature, (2) to confirm the usefulness of the indicators identified through an empirical study on a sample of SMEs and (3) to develop a new tool for lean change assessment based on the most suitable elements for SMEs confirmed during the empirical study.

2.2 Research Methodology

This research aims at providing a tool of assessment of changes towards lean production believed to be suitable for SMEs. In order to fulfill this aim, an array of research methodologies has been employed in this study as shown in Fig. 1.

As can be seen, the research starts with a review of the main existing models and frameworks for lean assessment in order to define a primary list contains the most common lean indicators and assessment tools. Although, the primary list is defined in such a way that it contains a minimum number of indicators, SMEs by virtue of many barriers are not able to implement this entire list at the same time. Therefore, a pilot study is conducted on a sample of SMEs in order to identify which indicators are suitable to use in SMEs. The findings of the pilot study will be the ground for the development of the lean assessment tool.

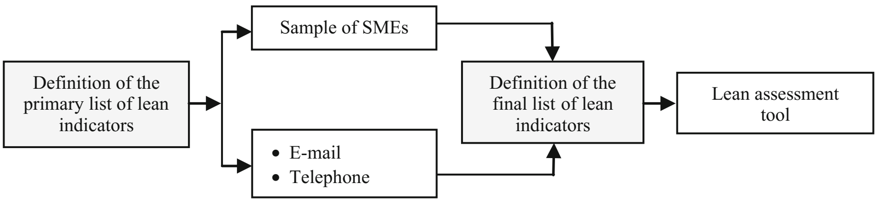

Fig. 1 Scenario adopted of the research methodology

3 Development of the Lean Assessment Tool

3.1 Definition of Primary List of Lean Indicators

Owing to their central role in economy's growth through a great flexibility and ability to innovate, SMEs are requested to transform their organizations basing on lean principles. To achieve this transformation, SMEs need to measure continuously their performance and their level of adherence to lean principles called "leanness level". The most common principles of lean production which have been mentioned in the literature are (Karlsson and Åhlström 1996; Åhlström 1998): (1) Elimination of waste, (2) Continuous improvement, (3) Multifunctional Teams, (4) Zero defects, (5) Just-in-time delivery, (6) Information systems.

These principles were used as cornerstones to develop frameworks and models of assessment of leanness level of companies. Based on works of several researchers (Karlsson and Åhlström 1996; Pakdil and Leonard 2014; Sánchez and Pérez 2001; Duque and Cadavid 2007), a literature review has enabled to group a set of most common assessment indicators used during lean implementation. Notice that the number of indicators has been kept to a minimum focusing on the most simple and quantitative indicators which are based on user control magnitudes in order to be more suitable to SMEs. Table 1 presents in detail the lean indicators examined.

As shown in the table, there are many lean indicators to measure the progress of each lean principle. Some of them are based on time measure (such as set up time, changeover time, lead time, takt time, cycle time, downtime…), while others are expressed as a percentage (defect rate, Percentage of employees working in teams). In a nutshell, a total of 28 indicators are identified.

3.2 Identification of the Final List of Indicators: Pilot Study

3.2.1 Data Collection

In order to evaluate the usefulness of these indicators, a pilot study based on an email survey is conducted among small and medium sized Enterprises. For that, the list (28 indicators) were sent to a sample of 110 companies which were asked to rate each indicator under a five-point interval rating scale (1-very Low, 2-Low, 3-Medium, 4-High and 5-Very High) to indicate the degree of use of each indicator in their companies. Three months after the lunch of the study, 11 return of email were received by 11 small or medium scale companies.

Table 1 The primary list of lean production indicators empirically examined in lean literature

Lean principles	Indicator	Change	1	2	3	4
Elimination of waste	Set-up time per unit	↓	x	x		x
	Changeover time/total production time	↓		x	x	
	Total down time/total machine time	↓	x	x		x
	Takt time/cycle time	↓		x		
	Manufacturing lead time	↓		x		
	Preventive maintenance time/total maintenance time	↑			x	
	Number of parts (trips) transported * distance	↓				x
Continuous improvement	Number of suggestions per employee and year	↑	x	x	x	
	Total number of implemented suggestions/total suggestions	↑	x	x	x	x
	Total number of problem solving teams/total employees	↑		x		
	Total number of improvement activities organized	↑	x			
Multifunctional teams	Percentage of employees working in teams	↑	x		x	
	Average frequency of task rotation	↑	x		x	
	Total number of employees capable of assignment rotation/total employees	↑				x
	Total number of employees working in teams/total employees	↑	x		x	
	Total number of job classifications/total employees	↓	x	x		
Zero defects	Defect rate	↓	x	x	x	x
	Total defectives costs/total sales	↓		x		
	Total number of people dedicated primarily to quality control/total employees	↑	x	x	x	
	Percentage of inspection carried out by autonomous defect control	↑	x	x	x	x
Just-in-time delivery	Total work in progress/total sales	↑	x	x	x	x
	Total number of orders delivered just in time per year/total number of deliveries per year	↑	x		x	
	Average production and delivery lot sizes	↓		x	x	x
	% of the total annual value or throughput of the system that is scheduled through pull mechanisms	↑	x			x
	Average total number of days from orders received to delivery	↓		x		x
Information systems	The frequency with which information is given to employees	↑	x			x
	Percentage of procedures that are documented in the company	↑				x
	Number of different measures used to assess the performance of the teams	↑	x			

Note ↑ the indicator should increase, ↓ the indicator should decrease
(1) Karlsson and Åhlström (1996), (2) Pakdil and Leonard (2014) (3) Sánchez and Pérez (2001) (4) Duque and Cadavid (2007)

3.2.2 Data Analysis

After completing data collection, these data has been exported into Microsoft Excel in order to calculate average and variance of variables.

First of all, a reliability test was performed based on cronbach's alpha to ensure that the survey results were reliable. The result of the test is presented in Table 2. Since an alpha of 0.7 indicates acceptable reliability and 0.8 or higher indicates good reliability, survey results are considered as highly reliable because the cronbach's alpha calculated is 0.81.

In order to further reduce the number of indicators to be simpler and more suitable for SMEs, the indicators with average rate below to the mean (3.00) are excluded. Thus, the list of indicators becomes as presented in Table 3.

As can be shown in Table 3, only 12 indicators from the primary list have an average rate higher than the mean of 3.00. These indicators form the final list of the most useful indicators for SMEs investigated that will constitute the basis of the lean assessment tool.

Table 2 Reliability and validity results

Number of items	Cronbach's alpha
28	0.81

Table 3 The final list of the most useful lean indicators in SMEs investigated

Lean principle	Ref	Indicator	Average	Variance
Elimination of waste	X11	Total down time/total machine time	4.36	1.05
	X12	Takt time/cycle time	3.52	1.96
	X13	Manufacturing lead time	3.00	1.89
Continuous improvement	X21	Total number of improvement activities organized	3.11	1.49
	X22	Total number of problem solving teams/total employees	3.00	0.12
Multifunctional teams	X31	Percentage of employees working in teams	3.4	0.16
Zero defects	X41	Defect rate	4.64	0.45
	X42	Total defectives costs/total sales	4.42	0.40
Just-in-time delivery	X51	Total number of orders delivered just in time per year/total number of deliveries per year	3.74	0.85
	X52	Total work in progress/total sales	3.00	1.49
Information systems	X61	Percentage of procedures that are documented in the company	3.63	1.62
	X62	The frequency with which information is given to employees	3.4	1.36

3.3 Proposed Lean Assessment Tool

Based on the results of the pilot study conducted on a sample of SMEs, the number of lean indicators was reduced to 12 indicators that are believed to be suitable for SMEs. The ultimate objective of this research is to propose a simple assessment tool that groups these indicators in a harmonized and standardized measure. The measure proposed is:

$$h_i = 1 - \frac{\sum_{j=1}^{j=n} (-1)^c \frac{(x_{ij} - x_{ij0})}{x_{ij0}}}{n} \quad (1)$$

Where:

- h_i: Leanness score of the principle i
- n: number of indicators to assess the lean principle i
- x_{ij}: the value of the lean indicator
- x_{ij0}: the target of the indicator x_{ij}
- c: coefficient that is equal to 1 if the indicator must increase or 0 if the indicator must decrease

To clearly demonstrate the methodology proposed, Table 4 presents an example of leanness score calculation.

Table 4 Example of leanness score of lean principles calculation

Lean principle	Indicator	Indicator value	Indicator target	Coefficient c		hi
Elimination of waste	X11	1,9%	1%	0	0.10	
	X12	0.74	1	1	0.74	
	X13	7.92 days	5 days	0	0.42	
			Score h1			**0.42**
Continuous improvement	X21	31%	90%	1	0.34	
	X22	45%	60%	1	0.75	
			Score h2			**0.55**
Multifunctional teams	X31	62%	80%	1	0.78	
			Score h3			**0.78**
Zero defects	X41	3.07%	2%	0	0.47	
	X42	2.12%	2%	0	0.59	
			Score h4			**0.53**
Just-in-time delivery	X51	52%	95%	1	0.55	
	X52	0.07	0.09	1	0.78	
			Score h5			**0.66**
Information systems	X61	30%	60%	1	0.5	
	X62	4 days	2.5 days	0	0.4	
			Score h6			**0.45**

As seen in the table, the proposed tool is a very simple way that SMEs can easily use to calculate their leanness level. According to this example, all lean measures must be transformed to be more harmonized and simple. Note that organization may also calculate their total leanness score that is the average of the individual leanness score of each lean principle.

4 Conclusions

The central aim of this paper was to develop a lean assessment tool that is confirmed as suitable for SMEs. The main assumption is that SMEs cannot just adopt, fully, the existing models designed for their large counterparts. They need an assessment model typically revised and adequate to their needs and characteristics. With this view, the main existing models of lean assessment have been reviewed to derive a basic list of lean indicators that have been further simplified based on the findings of a pilot study among a sample of 11 SMEs. Finally, a tool containing of 12 indicators with a method of harmonization of measures was established.

Since it provides for SMEs' managers a solid tool to redirect their efforts during lean transformation in a simple way, the proposed tool seems to be a quantum leap to support the efforts made by SMEs toward the operational excellence.

However, and to further improve its fulfillment the authors recommend a validation of the proposed tool by carrying out an implementation in a typical organization. Moreover, the tool could be enriched by studying other experiences as case studies or even surveys.

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Project-Based Learning as a Bridge to the Industrial Practice

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Abstract It is expected that engineering students develop both technical and transversal competences for the professional practice during their initial training period. The development of such competences can benefit from the interaction with real industrial contexts. Since project-based learning is an educational approach in which teams of students can tackle a given problem related to their future professional practice, this will be an outstanding opportunity to bring them together with industrial engineering professionals throughout the whole degree period and not only at its end. In this way, teachers will facilitate the development of the expected professional competences. This work aims to analyse a project-based learning approach that has involved six teams of students dealing with real industrial problems and challenges, and to evaluate the results based on the proposed technical solutions, as well as on the perception of five companies' representatives. Most of the proposed solutions were centred on Lean applications and ergonomic improvements of the analysed workplaces. Companies were very pleased with the developed projects and are willing to continue the interaction with the university in this context.

Keywords Project-based learning · Engineering Education · Industrial Engineering and Management · University-Business Cooperation

1 Introduction

Industrial Engineering and Management (IEM) professionals need to solve interdisciplinary problems, mobilizing knowledge from different areas of knowledge, like production planning and control and ergonomics, and resources that are transferable between different professions and functions, like teamwork and leadership.

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This mobilization of resources results in the application of competences (Le Boterf 1997) to solve specific professional problems. Competences related to specific technical areas of IEM are referred in this work as technical competences. Competences that can be transferred between different professional areas and functions will be referred in this work as transversal competences. A study from Lima et al. (2013) showed that job advertisements for IEM professionals have much more inputs for transversal competences than for technical competences or areas of professional practice. The need for developing transversal competences is reinforced by engineering accreditation bodies (ABET 2013; EUR-ACE 2008) and several IEM profile studies (Mesquita et al. 2015; IIE-Ireland 2012). A previous work showed that the majority of the courses of a IEM degree do not formally specify what transversal competences can be developed in each course (Mesquita et al. 2015). Furthermore, in the comparison of several European IEM curricula, it is not clear that students can interact with companies during their initial training phase (Lima et al. 2012).

The integrated development of technical and transversal competences aligned with the profession can be seen as a requirement for developing adequate academic curricula for the initial training of engineers. In the perspective of The European Union initiative, University-Business Cooperation (UBC) (European_Commission 2007), "Universities must also provide knowledge and skills geared to the needs of the labor market. In other words, graduates' qualifications must meet the needs of the labor market". In this context, the creation of opportunities for students to interact with industrial companies can be seen as a way to contribute for the development of those competences. This interaction can be promoted through visits to industries, seminars from professionals, internships, direct contact between students and professionals or with projects developed by students for solving real industrial/business problems. The direct integration of curricular opportunities for the development of projects in interaction with companies is classified by Zabalza (2011) as *practicum*. The engineering report from UNESCO (2010) reinforced the need for changing the pedagogical methodologies and apply active learning methodologies, peer instruction, problem and project-based learning. Merging the need for interaction with industrial practice and the development of innovative methodologies, project-based learning (PBL) is one of the pedagogic approaches that can be applied for developing curriculum with *practicum* opportunities. In this work, project-based learning is focused on the development of a project in a real professional context, in which teams of students solve an interdisciplinary problem, articulating theory and practice during the development of a project (Graaff and Kolmos 2007; Powell and Weenk 2003).

Despite the fact that a few works report on projects with interaction between external agents, students and teachers (Lima et al. 2015, 2014; Soares et al. 2013), there is still the need to study the way these projects are developed, in order to define the technical approaches that facilitate an interaction with industries, that intentionally create benefits for students' learning and for the companies. As a contribution for reducing this knowledge gap, this paper aims to describe projects developed in industry by students in the 4th year of a 5 year engineering degree

(7th semester) and evaluate those projects based on the technical solutions achieved and on the professionals' perspectives.

With the purpose of describing the technical solutions developed by students' teams, an analysis of the project reports and blogs (the two main deliverables of each students' team) was carried out. This analysis permits to identify the main technical contributions of the developed projects, both for the development of the expected competences and for the improvements and innovation expected by companies. In this work, the evaluation of the process is based on five interviews conducted with professionals from five different companies. The interviews were analysed by two researchers considering two main dimensions: positive results for the company and main difficulties of the process. In this way, the researchers can develop a deeper understanding of ways to develop this type of projects and how to create sustainable relations with industries in this context.

2 PBL Context

The PBL edition analysed in this work involves six teams of students from the 7th semester of the Integrated Master Course on Industrial Engineering and Management (IEM) and it is formalized in the curricular structure through the Integrated Project on Industrial Engineering and Management II course (IPIEM II). The other courses of the semester, (i) Production Systems Organization II (OSP2), (ii) Production Information Systems (SIP), (iii) Simulation (SIM), (iv) Ergonomic Studies for Workstations (EEPT) and (v) Production Integrated Management (GIP) are project-supporting courses.

Each students' team is associated to a company (six companies are involved) and, in general terms, the main stages of the project are: (i) analysis and diagnosis of the company's production system and (ii) development of improvement proposals. In the first stage, and in the context of each one of five project supporting courses, students' teams use different representation and analysis methodologies/tools to evaluate the production system and identify problems. In the second stage, the teams should develop improvement proposals, using the different intervention tools/methodologies provided by the project supporting courses, in order to deal with at least one of the identified problems. In this particular IPIEM II edition, developed from mid September 2015 to mid January 2016, the main proposals where developed in the areas of Lean Manufacturing and Ergonomics. In fact, contrarily to the first stage, where all the supporting courses' subjects should be properly addressed, in the improvement proposals' stage a single theme might be considered if, obviously, both the inherent workload and relevance for the company are adequate.

During the whole semester, the project is accompanied by a coordination team composed by the teachers of the project supporting courses, the team's tutors and the researchers that provide pedagogic support to IPIEM II. Furthermore, professionals from the six companies involved in this edition also support the project (company tutors). The companies are from several types of industry: (Company C) textile yarn and fabrics for the automotive industry, (L) electrical wiring for industrial machinery, (V) electrical capacitors (I) furniture, (S) files and handsaws, and (R) plastic films for packing. In brief terms, the main production processes involved are: company C—winding (yarn), weaving (fabrics) and finishing; company L—cutting (wires), interlacing (cables), and welding/crimping (connectors/terminals); company V—winding (insulators and conductors sheets) encapsulation and welding (terminals). Companies I and S involve the typical processes of the wooden furniture and metal mechanic industries, respectively. Finally, in company R the main process is the extrusion of the plastic film.

3 Technical Solutions Developed by Students

Tables 1 and 2 present a compilation of the main technical solutions developed and proposed by the students' teams at each company. All the solutions were based in a previous diagnostic of the production system. Allowing to establish a link between the type of solution and the involved companies, the reference of each case is composed by a first letter, which identifies the company, and by a number that represents the order presented here. Other aspects of the proposed solutions, with more detailed data in some cases, are not presented here due to obvious space limitation purposes.

Table 2 presents an analysis of the expected impact for the company and the estimated time of implementation.

4 Process Evaluation

For the purpose of evaluating the perspective of the professionals regarding the difficulties and the impact of the students' projects, five interviews were conducted in five companies. A short summary of each type of difficulty and impact is presented and then supported by at least one transcription.

The overall perspective of the companies was positive, but some of them pointed the following difficulties: (i) the need to involve areas of the company that are not under the control of the company tutors; (ii) the workload needed to evaluate and implement solutions proposed by the students; (iii) difficulty to deal with some questions that are to generic; (iv) difficulty to be available to interact with the students in some specific occasions.

(i) "They asked for freedom to be able to contact various departments, some of which are not under my jurisdiction and I had to ask my colleagues to facilitate access." Company L, Professional 1

Table 1 Proposed solutions according to their category

Category	Case	Problems identified	Drawn solution
OEE monitoring & improvement	R1	No recording history. No recording culture	Definition of paper forms to record data. Construction of excel sheets to store, compute and display results. The worksheet developed computes data and creates reports and important graphs
	L1	Very low OEE (27%) due to high number of setups	Apply SMED. Changes in setup standards; Small changes in the machines to allow parallel activities; One more operator in the setup
Cell layout and flow improvement	R2	High levels of transport and motion waste. Complex flows of materials	Machines were moved to better locations and some machines were also changed to separate loading from unloading
	L2	High inventory; transport and motion waste; unbalanced workstations	Machines were moved to locations according to main flow. Workstations were balanced and the batches were reduced
Internal Logistics	C1	High levels of WIP; lack of flow; communication problems	A pull system in the supply of materials and a better layout for materials warehouse
	S1	High variability of the mizusumashi routes	Better layout of the supermarkets and new standards for mizusumashi routes
Cell balancing and setup reduction	V1	Large WIP; unbalanced cell; low productivity; long setup times	New layout and better balanced work
Physical environment improvements	R3	Low levels of lighting in visual demanding workplaces	Increasing the number of lamps and its power, considering also a uniform distribution along the workplaces area (>300 lx)
	V2	A noise exposure higher that the threshold established by the Portuguese legislation	Noise attenuation measurements through the implementation of physical encapsulation of the feed area of the machine
Manual materials handling and critical postures	R5	High-risk activities were identified in a section of the company	The proposal includes the adoption of a mechanical aid, consisting in a mechanical crane with a pressure application pinch that can be used to lift and lower the heavy loads

(continued)

Table 1 (continued)

Category	Case	Problems identified	Drawn solution
	S2	Frequent load handling in very low shelves	Redesign of the transport trolley, with a new design and placement of the shelves. The trolley will be completely redesigned and shelves can be moved through a pedal
	V3	Excessive load when handling the finished product boxes	Redesign of a plastic box with lower capacity and handles
Accident prevention	L5	Possible fall out of the reels when they are being used at the warehouse shelves	Reels should be protected by a barrier mechanism that can be easily opened when a specific reel is being used. Create a "two-arms" barrier that can be easily opened
	C2	The handling of the fabric rolls and the transport to the expedition truck is done manually and with a fork-lift truck, representing a clear accident risk factor	Several measures can be adopted, including the handling of the rolls based on a mechanical "arm" and the rolls palette should be specifically designed to avoid the movement of the rolls. More flexible handling of the fabric rolls

(ii) "Now, at this time, I can get interesting data they have, but I will have a lot of work in order to apply it here on the company and I have to pick up from the beginning." Company V, Professional 1

(iii) "There was a situation that happened specifically in that they sent me a report for me to fill. And I asked them if they thought I had nothing else to do… cannot be like that, send me a report asking for information that I would have a lot of work to get." Company V, Professional 1

(iv) "Our availability is not always what we would like to have… even though we think that is a negative point, in their feedback was one of the positive points, the support we gave them during their stay here." Company S, Professional 2.

Companies' representatives were asked about what were the main advantages of this type of project that contribute to maintain the interest of the company in the process. Several companies described the advantage to have (i) outside people looking to their system with a fresh look. Another advantage pointed by the companies was the (ii) opportunity to have extra workload from the students' teams to analyse their system. Additionally, there is an interest in the (iii) technical results obtained by teams and in the (iv) updated knowledge that the academy can bring to them.

Table 2 Analysis of the expected impact and estimate time for implementation

Case	Expected impact	Time
C1	Reduction of 50% in WIP	Medium
C2	The impact in terms of the reduction of handling load for the operator will be quite high. The cost of the measure will be also significant	Long
I1	22% in setup time reduction	Short
I2	There will be a cost impact, as this investment can represent approximately 12 k€, but it is expected to be compensated by a decrease on WMSDs development and in a boost in operators' motivation	Medium
L1	Reduction of setup time from 11 min. to 6 min. This will improve OEE	Medium
L2	77% reduction in transport distances. WIP reduced in 50%	Short
L3	Improvement in the operator postures, avoiding critical posture when using the keyboard. Pain complains on the shoulder and elbow areas are expected to decrease	Short
L4	Better thermal environments and avoiding possible heat stress situations without compromising the workplace lighting	Short
L5	Accident sue to reel fall can be prevented and the corresponding consequences eliminated	Medium
R1	Better knowledge of machine utilization. Productivity improvements	Short
R2	Better access to load and unload materials. More utilization of worker in value adding activities. Better material flows. Higher productivity	Short
R3	Increased lighting levels, with the corresponding increasing well-being of the workers. Potentially reducing visual problems that can arise later. Less probability to make errors and improved quality	Medium
R4	The use of hearing protection devices will result in a significant reduction on noise exposure, to levels below the maximum threshold considered by law	Short
R5	The decreasing of the manual handling, as well as the decrease of the loads in some activities, will represent a decrease in the risk, estimated by a risk assessment method. This will have a significant impact at the absenteeism and/or in the reported pain or discomfort by the involved workers	Medium
S1	30% less time spend in the supermarket and 20% less time in the mizusumashi routes	Short
S2	A significant reduction on the adoption of critical postures as demonstrated by the application of a posture risk assessment tool	Short
V1	Reduction from 7 to 5 workers; reduction of lead time in 68%. Setup reduction from 87 to 29 min	Short
V2	Less noise exposure and avoid to have operators with a personal exposure higher than the daily threshold value	Medium
V3	Manual handling will be significantly decreased and WMSDs risk will be minimized	Short

(i) "There was a proposal it has more to do with the wellbeing of the people and the noise reduction between areas. They proposed placing a gate that divides two areas, I think the idea was a "rapid roll door" that quickly closed after the passage. We never had reminded about that option, but I think it is an option quite valid to mitigate, or at least prevent, that the people of the quietest part of the factory suffer from the noise of other part." Company C, Professional 1

(ii) "It's not just *think outside the box*, we're here with a difficulty, lack of availability… they bring knowledge and apply and have this dedication and this availability." Company R, Professional 1

(iii) "Two proposals they make for the cutting machines… They were able to produce results that will give gains in the order of 2 min, passing from 4.75 to 2.75 min. In a sector that has 14 cutting machines working in two shifts, with an average of 500 setups per day, we are talking about more than a thousand minutes, which means one machine gain!" Company L, Professional 1

(iv) "I think that it only brings advantages in terms of improvement and know-how for the company, and the links between businesses and universities, I think we all have to gain from this type of project." Company C, Professional 1.

5 Conclusions

It is believed that project based learning in real context is a very effective way for students to build solid professional competences. In this work, different industrial engineering students' teams had to go through real projects in industry under a project based learning framework. In this context, students' teams had to identify problems or improving opportunities and develop effective engineering solutions for companies. This article reports several effective solutions in ergonomics and lean manufacturing areas, with very good results in terms of performance and ergonomic improvement according to feedback from teachers and professionals from those companies. The presented solutions in lean manufacturing areas included OEE monitoring implementation; OEE improvement; setup reduction through SMED; Cell layout, balancing and flow improvement; and Internal logistics systems improvements. In the ergonomics and human factors related areas, the solutions included Physical environment improvements; Manual material handling improvements; Critical postures reduction; and Accident prevention.

The feedback from professionals of the companies involved is very positive as can be shown in statements such as: "Indeed the complexity is to go from complex to the simple, and I think they realized very well the objective and what was the purpose of work"; "I think it makes perfect sense, these projects are an added value both for the university and for companies, for the labour market, and Portugal needs it!"; and "Thank you for sending such people".

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Wiki as an Activity Learning

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Abstract The purpose of this paper is to analyse the design of an activity based on wiki technology in a Higher Education environment, specifically in engineering studies. The issues proposed here are based on the previous experience of the authors by developing a wiki activity in the field of industrial engineering. Wiki is considered a type of Web 2.0 technology that enables users to work together on the Web. The research literature reports a number of experiences with wiki-based collaborative writing in education. However, to enable all the advantages as far as possible, a clear specific description of the activity is mandatory for both students and teachers. This work confers guidelines as to how wikis will be developed and evaluated. Regarding developing wikis, the content of this task is specified in collaboration with the instructor. Regarding assessments, the quality of the wiki-page and possible competences developed should be considered. The methodological design presented herein intends to act as a basis for the wiki-based collaborative writing approach. In addition, a list of assessment indicators that can be the basis for a future research line related to an automated tool for evaluating wiki is provided.

Keywords Wikis · Work group · Collaborative work · Engineering studies · Competences

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1 Introduction

This paper aims to describe the design of an activity based on wiki technology in a Higher Education environment, based on the experience of developing a wiki activity in a course of Operations Management (OM) in industrial engineering studies. According to Leuf and Cunningham (2001) a wiki is a set of linked web pages, created through the incremental development by one or a group of collaborating users and the software used to manage the set of web pages (Wagner 2004). Put simply, a wiki is an editable website that is created incrementally by visitors working collaboratively (Cole 2009). The first Wiki was developed by Ward Cunningham in 1995, as the Portland Pattern Repository, to communicate specifications for software design. The term Wiki (from the Hawaiian Wiki-wiki meaning "fast") gives reference to the speed with which content can be created with a Wiki. The most famous example of a Wiki is the online encyclopedia, Wikipedia.

The work of Fountain (2005) and Parker and Chao (2007) are a detailed survey of the state of wikis in education. The advantages of using wikis in teaching are those associated with collaborative work (Lamb and Johnson 2007; Maset Pujolás 2009); wikis allow interaction among all members of the educational community to obtain a greater better tracing of the teaching-learning process. Firstly, to include content in wikis, student must read the content already in it, and contribute to their personal reflection and critical thinking process. After reviewing the content, students will research the topic to extend their knowledge. Then they have to be able to integrate new information into a topic that is already written, which encourages their independent learning and innovation. The writing process itself will help develop language skills (Canton 2013), which are substantially impaired nowadays. In addition, students are motivated to share their content and they experience how this can enrich them in many ways by fostering effective communication and social responsibility. Secondly, by integrating collaborative work into a website, all the above-described activities are promoted, which increases students' participation and motivation. This web technology allows results to be published and disseminated, access to various information sources, contextualization of contents and digital information processing. According to Kolodner and Guzdian (1996), collaborative learning technology environments create more in-depth knowledge, which contributes to lifelong learning.

Regarding the assessment of the wiki, some recent research trends propose peer assessment (Wever et al. 2011). However, these studies usually analyse the impact of these types of assessment without detailing how to evaluate the quality of the content of the wiki. Because of the proper nature of the wiki, it makes sense to consider obtaining automatic indicators that could help the instructor to the evaluation of the content. At the University of Cádiz (Palomo Duarte et al. 2011) there are several projects developed in this area. However the parameters considered for the assessment of the quality of the content of the wiki (mainly bytes) could be completed to improve the assessment of the wiki. Dalip et al. (2009) explore a significant number of quality indicators and study their capability to assess the quality of Wikipedia article. Nevertheless many of them are too complex and cannot be applied in the educational environment in which this work arises. Thus in this work it seems appropriate to list the aspects that should be measured on a wiki to assess their quality. On the issue of competence assessment we found very recent works in Martinez, and Moral Perez (2011) and Gallego-Noche et al. (2014). In this paper we address those competences that the authors believe could be assessed according to the design described activity.

The reminder of the paper is structured as follows: in Sect. 2 the design of the activity to be performed in the wiki are described; in Sect. 3 the aspects to evaluate in the wiki strategies are addressed; and finally, Sect. 4 provides the conclusions reached and future research lines.

2 Designing the Activity to Be Performed in the Wiki

This section intends to provide an example of wiki activity to develop it in a subject matter. A design is considered whose application in most courses of industrial engineering and other areas might be valid. Firstly, the content of the activity is described, followed by the methodology. This paper is considered from the authors' experience in a course of Operations Management (OM) in industrial engineering studies. The wiki from the experience can be found at valuador.doe.upv.es/wiki. This is why the examples are about this theme. However, they can be extrapolated to other subject matters in engineering degrees.

2.1 Task to be Done

The objective of the activity is to develop a compendium of concepts. The concepts to be developed will be those of each subject matter. This consideration is believed suitable because it is hard to find online material in specific engineering fields that adequately develop the specific concepts in the area. Although most of these concepts can be found in the literature, they are scattered around and consulting them is not practical. As the lists of concepts to be developed in each specific field are very long, those terms that relate more to the material to be taught in this course must be selected.

In accordance with the application case considered, for the Operations Management (OM) subject matter, we could consider the initial list represented in Table 1. As we can see concepts can be classified as those that need to be more or less fully developed.

Table 1 Operations management, example of list of concepts

Short concepts	Large concepts
Offshoring; Incoterms; Intermodal; Direct Product Profit; Learning effect SPC; QFD;Value analysis/Value engineering (AV/IV); PPAP; Keiretsu Panamax; ISO 14040/44; GTIN ROLA—Return on logistics assets CO2; Foot Print Cross Docking SKU; GS1; ISO 16949; Paynter Chart; Environmental Friendly Packaging; Keiretsu; DMAIC	Supplier Development; RAL—Level Service Indicators; RAL—Reusable Transport Items; Group Technology RAL—Cross Docking Process; RAL—Loading and unloading processes; RAL—Efficient loading units; Traceability systems; RFQ Package; RAL—Delivery and receipt Full load processes, RAL—urban freight; Corporate Social Responsibility; Green Logistics; Taguchi methods; RAL General Principles of Operation Pallet Pools; Supplier Assessment; Fleet Management; RAL—Concerted quality Supplies; RAL—Delivery and receipt Partial Shipment processes; WMS; FMEA; Life Cycle Assessment; Mass Customization

This activity can be done individually or in groups. If done in groups, as will be mentioned in Sect. 3 on the aspects to be assessed in the wiki, the possibility of being able to assess the team group's competence is considered. According to Tonkin (2005) there are four different forms of educational wikis: single-user wikis allow an individual to collect and edit his or her own thoughts using a Web-based environment; lab book wikis allow students to keep notes online with the added benefit of allowing them to be peer reviewed and changed by fellow students; collaborative writing wikis can be used by a team for joint writing and finally knowledge base wikis provide a knowledge repository for a group. So, at this work are considered all this options for educational wikis except lab book. For the OM subject matter, the 23 registered students were asked to consider undertaking the activity on an individual basis. The two concepts to be developed were handed out to each student: one to be less developed and another to be more developed. This activity represented 10% of the total subject matter mark.

2.2 Development Sequence

This section lists the various process stages of this wiki activity. The person in charge of each activity is the subject matter teacher, unless the student is specified to be responsible for this.

1. Identify the number of students
2. Set the value that the wiki activity will have
3. Make a list of concepts. The number of concepts has to agree with the number of students and the evaluation that we wish to give the activity

4. Distribute concepts among students either individually or as groups. If you have decided to use groups, they should have already been formed
5. (students) Develop their own wiki activity: as individuals or groups, students work on developing a wiki
6. *Evaluate qualitatively and quantitatively the wiki work done by the student or by groups
7. *Evaluate competences through the wiki
8. Distribute the concepts to be revised/completed and evaluate them with students as individuals or as groups
9. (students) Revise and evaluate the wiki activity of classmates as individuals or groups
10. Evaluate qualitatively and quantitatively the wiki work done by the student or by groups, and the revisions/modifications made of other classmates's wikis
11. *Evaluate competences through the wiki
12. Include the evaluations to obtain a final evaluation

As the degree and master subject matters are continuously evaluated, the qualitative and quantitative process is alternated and scaled in time according to the subject matter development that the teacher considers. With the OM subject matter, two proportionally distributed dates are considered during the 4-month period when students knew that their wikis and/or revisions of wikis were going to be evaluated.

3 Aspects to Assess When Developing a Wiki

Below is a list of all the aspects that can be assessed when developing a compendium of concepts as a wiki. The objective is for students to develop quality content through the wiki. When assessing the quality content, the following must be considered:

- Depth, Length, Structure, Reading clarity, Connection with concepts, Opportunity of contents, Topicality

When developing the work content in a wiki support, there are several indicators that can be automatically measured and which contribute to assess wiki quality. They are:

- Quality of the spelling and grammar in the presented text through automatic spelling and grammar checkers
- Word count in own wikis or when revising others' wikis
- No. of paragraphs in own wikis or when revising others' wikis
- No. of sentences in own wikis or when revising others' wikis

- No. of figures in own wikis or when revising others' wikis
- No. of consulted sources in own wikis or when revising others' wikis
- No. of external links in own wikis or when revising others' wikis
- No. of internal links in own wikis or when revising others' wikis
- Count of student's wiki activity according to time. Using the bytes measure is an interesting option to join student's activity

As for the competences that could be developed when performing this wiki activity, we can include the following:

- Comprehension and integration. This competence involves demonstrating knowledge comprehension and integration in specialization terms and in other broader contexts. For the development of the wiki is not due to make a copy paste from other web pages. It is seeking information from different sources and be able to understand them and integrate them into the wiki.
- Ethical, environmental and professional responsibility. Acting responsibly in ethical, environmental and professional terms with one and with others. Do not make plagiarism and always cite sources.
- Effective communication. This competence involves communicating effectively in writing and orally, and suitably using the necessary resources and adapting to the characteristics of each given situation and audience. In this case, written communication is developed. Clearly in the wiki written communication is developed.
- Team work and leadership. Working and leading teams effectively to achieve common objectives by contributing to develop them personally and professionally. In the case that the wiki is done as a group, that competence is developed.
- Lifelong learning. This competence implies using learning strategically, autonomously and flexibly throughout one's life and according to the pursued objective. According Kolodner and Guzdian (1996) this type of work contributes to lifelong learning.
- Planning and managing time. Suitably planning the time available and programming the necessary activities to achieve academic, professional and personal objectives. Whether the work is done individually and as a group the student must organize the available time to perform the activity.
- Specific instruments. This competence implies the capacity to use techniques, skills and the up-to-date tools needed to practice one's profession. Students learn the use of the wiki tool.

The below Fig. 1 shows how the proposed indicators relate to the evaluation of the content and competence assessment.

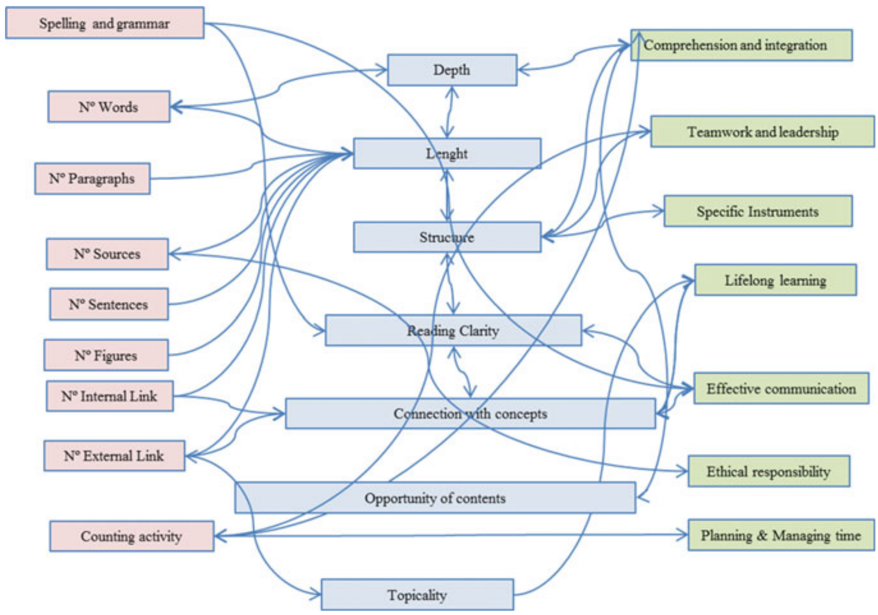

Fig. 1 Relation between concepts

4 Conclusions and Future Work

This paper from the experience of the authors in the development of a wiki in a subject of industrial engineering environment, propose a design of a wiki activity. This design can be easily extrapolated to more subjects in the area.

Regarding the assessment of the quality of the content of the wiki in the related literature authors don't find complete assessment grids which can be adapted to this environment. So, authors list aspects to assess when developing a wiki. This list can be considered a basis for the establishment of a future rubric for wiki. In addition it is very interesting propose a future design that automates the value of many of these aspects facilitating the task of evaluation of both content and competences.

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