Modeling and Simulation of Logistics Flows 2

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Jean-Paul Bourrières

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Dashboards, Traffic Planning and Management

Jean-Michel Réveillac

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Contents

About This Book

There are already several works about logistics, operational research, decision support, the theory of graphs, dynamic programming, etc., but few of them gather all of these domains together by proposing an overall vision that focuses less on pure and hard mathematical aspects, without totally ignoring them, while offering numerous practical exercises.

This book is one of three volumes. This first volume tackles theoretical aspects with corrected exercises for each chapter, finishing with a presentation of the principal software systems dedicated to operational research (OR) and logistical simulation. The second and third volumes are dedicated to practice and specialized applications of software programs.

Most of the studies proposed here are able to be completed using a simple calculator, a sheet of paper and a pen or even with the help of a spreadsheet on Microsoft Excel, Apache OpenCalc, Apple Numbers, etc.

The presented techniques and their uses are multiple, yet I am sure that a student, a software programmer, a developer, a technician, an engineer, an IT specialist, a decision-maker and you, the reader, will find practical applications that were unexpected in your professional or even personal life.

Intended public

This work is designed for all those who encounter logistical problems linked to flux management, decision support, optimization of journeys or rounds, research for an aim when confronted with multiple constraints, creation of dashboards, relevant simulations, etc.

The works presented require a minimum level of mathematical knowledge, and a post A level student in science or economics will not encounter major difficulties. I tried to maintain simplicity and go straight toward the objective in the theoretical approach without going into great demonstrations, which to me do not seem necessary.

In terms of the practical exercises, on a laptop, tackled in Volumes 2 and 3, a good knowledge of the exploitation system (track, records and lists, files, names, extensions, sheet, movement, etc.) will prove essential.

Since a few works use a spreadsheet, it is thus necessary to master the basic functionalities of this type of software program. It will also be convenient to know the primary use of pivot table data manipulation tools.

If we know about *visual basic application* (VBA) language or its equivalent, we can easily understand, improve, enrich and create new solutions to certain problems.

Lastly, if we understand the basic systems for managing data and relational algebra, then we will be at ease in every domain explored.

Organization and contents of the book

This work is composed of three volumes:

– Volume 1: Theory and fundamentals;

– Volume 2: Dashboards, traffic planning and management;

– Volume 3: Discrete and continuous flows in 2D/3D.

Volume 1 presents an introduction followed by 10 chapters and a conclusion:

– approach for logistics;

– an overall view of operational research;

– basics of the theory of graphs;

– calculation of optimal routes;

– dynamic programming;

– planning and scheduling with PERT and MPM;

– calculation of waves in a network;

– hiding trees and tours;

– linear programming;

– modelization of route traffic;

– diverse software programs for RO and simulation of logistical flux.

Here, we will find the fundamental concepts needed in order to understand the second volume. Numerous examples accompany the theory and each chapter ends with a series of exercises with their solutions.

The conclusion, as indicated by the name, tries to establish a picture of the current state of theoretical logistics and its future development.

Appendices 1 and 2 bring a few other elements. We will find them in the following order:

– table of the law of the normal reduced center;

– a presentation and a mini-manual dedicated to the calculation software program GeoGebra.

Volume 2 starts with an introduction completed with four chapters that put into practice the software tools in cases of practical application in order to finish with a conclusion:

– the different tools used in this volume;

– operational research with a spreadsheet;

– dashboards with a spreadsheet;

– scheduling and planning with a project manager;

– simulation of route traffic.

The conclusion presents new functionalities that should appear on spreadsheets and project management systems as well as the evolutions and points of similarity between traffic simulators and new infrastructures that emerge in traffic networks.

Appendix 1 is dedicated to the installation of a solving tool in Microsoft Excel. Appendix 2 is consecrated to the installation of Java development kit.

Volume 3 starts with an introduction followed by four chapters dedicated to the modelization and simulation of flux in a 2D or 3D environment. Each case is different and taken from situations encountered in reality. A conclusion concludes this Volume 3:

– different software programs used in this third volume;

–simulation of discreet computerized flows;

–simulation of mixed flows;

–3D flows and evacuation simulation;

–3D flows for transporting and storing.

The conclusion conveys the future evolutions of software programs and their integration into society. At the end of each volume, we will find a bibliography and a list of Internet links. A glossary is also available that will elaborate on certain acronyms and some very specific terminology surrounding logistics and operational research.

Conventions

This book uses the following typographic conventions:

– *italics*: used exclusively for important terms used for the first time in the text, one can generally be found in the glossary at the end of the work mathematical terms, comments, equations, expressions or variables present in the theoretical and practical chapters among examples and exercises;

– *(italics)*: these are the terms in English or in foreign languages;

– UPPER CASE: these are reserved for names of windows, icons, buttons, files or lists, menus or submenus. This can also be elements, options or commands present in the window of a program;

– `courier`: this font is used for VBA code lines. These lines can end with the symbol ↵, which implies a return to the obligatory line when inputting.

Any comments are signaled by the presence of a keyword: COMMENT. They will complete the explications already provided. Theorems are signaled by the keyword: THEOREM. The figures and tables have captions to further their understanding.

Vocabulary and definition

Like for all techniques, logistical optimization tools have their own vocabulary. Words, acronyms, abbreviations and specific names that are not always familiar; this is the role of the Glossary found at the end of the book.

Acknowledgments

It is my particular duty to thank the team at ISTE, and my editor Chantal Ménascé who had confidence in me, Jacqueline Gélinier from the company 1point2, distributor of ExtendSim and PathFinder software programs, Clair Augsburger of FlexSim France, not forgetting my dear friend, Pascal Mauny, director of IUT of Chalon-en-Saône and lecturer at the University of Bourgogne, for the time and attention granted to me for writing the preface.

Finally, I would like to thank my wife, Vanna, who has supported me throughout writing this book.

Jean-Michel RÉVEILLAC
November 2016

Introduction

I.1. Logistics, information systems and software

The last chapter of Volume 1 of this series ended by looking at the software used for solving the different logistical problems that industrial, commercial and administrative structures face on a daily basis [REV 17a].

Since its inception, logistics has been omnipresent and has undergone significant development. Globalization, the explosion of the internet and the constant push to look to do everything better, quicker, more effectively and for less money, have greatly contributed to its expansion.

Although we are still only in the early stages, can we say that logistics has reached full maturity? Nothing could be less certain. The Internet of Things, still in its infancy, should profoundly change the normal rules relating to product management in the years to come.

The steps being taken by our cities towards becoming intelligent cities or "*smart cities"* will soon cause upheaval in our daily lives and our work habits, in public transport, in business and even in our own homes.

The centralization of many different kinds of data and the increase in central file storage has only just begun. We are currently living in a world of information systems and databases and that will continue to be the case in the future. However, aside from the impact this has on ourselves as individuals, our environment and the objects we use will be implicated in this massive warehouse of data that is currently being put together.

In 1997, the concept of "*big data"* first appeared. For many researchers this is one of the challenges that the information industry will have to deal with between

2020 and 2030: how to properly manage and analyze this enormous accumulation of content.

The optimization and the simulation of logistical flows plays an important role in this phenomenon. Data is collected and is then used to build models and structures in order to optimize constraints present in the field.

A variety of different types of software are used and can be divided into two categories: the specifics that deal with particular areas, such as *flow simulations* (extendSim, FlexSim, Arena, Witness), management and project *planning* (Microsoft project, Sciforma PS, GanttProject, MicroPlanner), calculating and *optimizing routes* (Gazoleen, Portatour, Mapotempo, Geoconcept, TourSolver), the management of *warehousing*[1] (Speed, Reflex WMS, Mecalux Easy WMS) and general applications, such as spreadsheets (Microsoft Excel, Apple Numbers, OpenOffice Calc) or calculation managers (Mathematica, Mapple, Xcas, GeoGebra).

In Volumes 2 and 3 of this series, I wanted to introduce you to the optimization and the simulation of logistical flows across some of these types of software. The ones that I chose and focused on are those that I use in my everyday work, not just in my role as an IT engineering consultant but also when teaching students.

The majority of the cases dealt with here come from practical cases that have been bowdlerized several times in order to avoid overloading how they are presented and to thus facilitate access for a novice who can then look into it further should they wish.

In this second volume, we will work successively with Microsoft Excel, the project manager Microsoft Project and the road traffic simulators, Ring road, RoadTrafficSimulator, Intersection simulator, Green Light District (GLD) and AnyLogic[2].

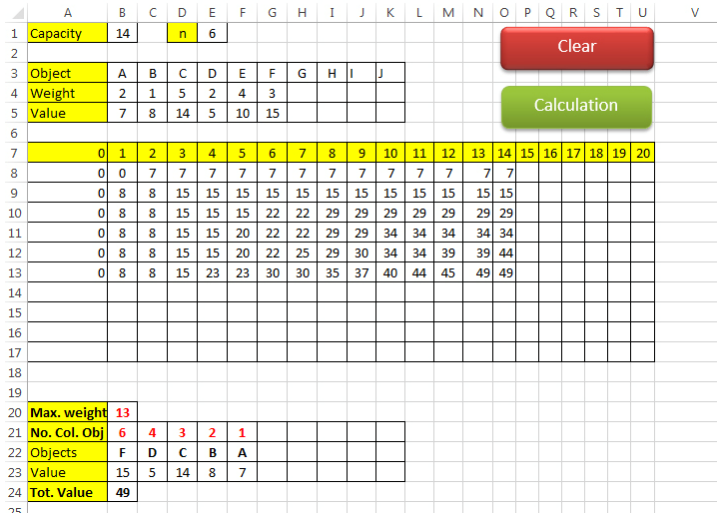
The studies carried out using spreadsheets will employ a number of the operational research techniques described in Volume 1 [REV 17a].

In turn, we will look at:

– Dynamic programming using the so-called Knapsack Problem (KP) problem solving method. This exercise will use a solution employing Visual Basic

1 Software for the management of warehousing is often referred to using the acronym Warehouse Management System (WMS).
2 Although Anylogic is a general flow simulation program, the example that I will present in this volume will focus on the modeling of road traffic.

Application (VBA) with which you will develop two detailed and commentated procedures.



Capacity	14		n	6																		
Object	A	B	C	D	E	F	G	H	I	J												
Weight	2	1	5	2	4	3																
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	0	0	7	7	7	7	7	7	7	7	7	7	7	7	7							
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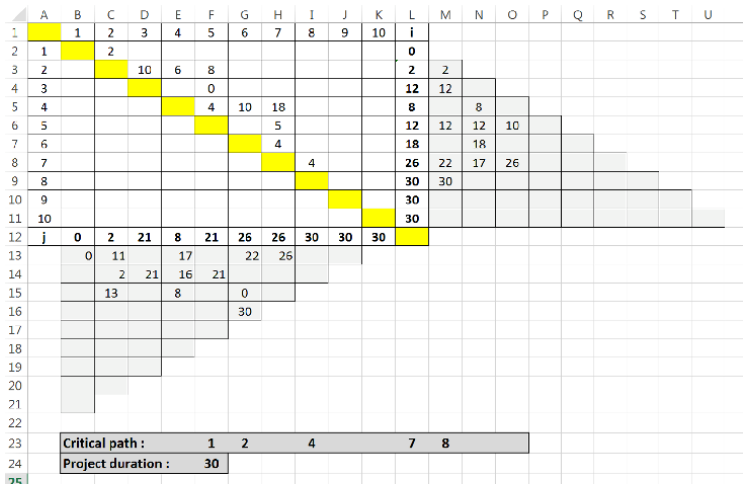
Max. weight	13																					
No. Col. Obj	6	4	3	2	1																	
Objects	F	D	C	B	A																	
Value	15	5	14	8	7																	
Tot. Value	49																					

Figure I.1. *Knapsack with Microsoft Excel*

– *Scheduling*: where you will design a critical path resolution matrix based on simple calculation formulae, the majority of which will integrate conditional instructions.



	1	2	3	4	5	6	7	8	9	10	i	
1		2									0	
2			10	6	8						2	2
3					0						12	12
4					4	10	18				8	
5						5					12	12
6						4					18	
7							4				26	22
8								4			30	30
9											30	
10											30	
j	0	2	21	8	21	26	26	30	30	30		

		0	11		17		22	26														
			2	21	16	21																
			13		8		0															
							30															

Critical path :				1	2		4				7	8										
Project duration :				30																		

Figure I.2. *A critical path calculation matrix*

– The planning of tasks will enable you to discover how a histogram can be used in order to generate a *Gantt chart,* either connected or unconnected to a calendar.

Project start date :		03/02/15		
Task	**Start**	**Duration**	**End**	**Variation**
A	**03/02/15**	**1**	**03/03/15**	**1**
B	03/03/15	10	**03/17/15**	14
C	03/03/15	5	**03/10/15**	7
D	**03/03/15**	**8**	**03/13/15**	**10**
E	03/03/15	4	**03/09/15**	6
F	03/11/15	2	**03/13/15**	2
G	**03/11/15**	**4**	**03/17/15**	**6**
H	**03/15/15**	**2**	**03/17/15**	**2**
I	03/15/15	1	**03/16/15**	1
J	**03/17/15**	**1**	**03/18/15**	**1**
K	**03/18/15**	**1**	**03/19/15**	**1**
L	**03/19/15**	**1**	**03/20/15**	**1**

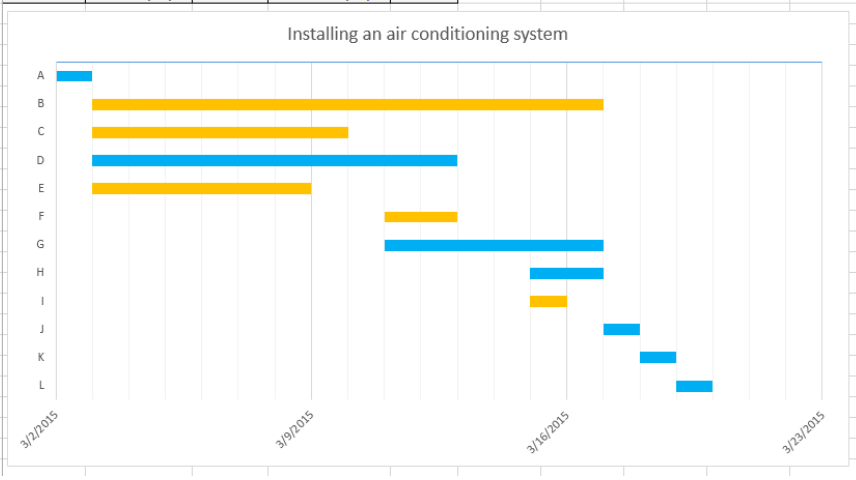


Figure I.3. *Gantt chart with Microsoft Excel*

– The management of *maximal flows* will lead you to implement, in the same way as dynamic programming, two detailed and annotated procedures in Visual Basic, connected to a spreadsheet.

– The *transport models* will be based on a tool found in Microsoft Excel, known as Solver. You will learn how to use it by inputting the different elements required for its use: objective, variables and constraints across the two examples.

	A	B	C	D	E	F	G	H
1	From	To	Flow	Capacity		Nodes	Net Flow	Supply/Demand
2	S	P1	6000	10000		S	14000	
3	S	P2	8000	8000		P2	0	0
4	S	P3	0	6000		P3	0	0
5	P1	P2	0	4000		R1	0	0
6	P1	R1	6000	6000		R2	0	0
7	P2	R1	4000	4000		R3	0	0
8	P2	R2	2000	2000		R4	0	0
9	P2	R3	2000	2000		R5	0	0
10	P3	P2	0	4000		P1	0	0
11	P3	R3	0	6000		T	-14000	
12	R1	R2	4000	4000				
13	R1	R4	6000	6000				
14	R2	R4	4000	4000				
15	R2	R5	2000	3000				
16	R3	R2	0	6000				
17	R3	R5	2000	2000				
18	R4	T	10000	12000				
19	R5	T	4000	4000				
20								
21								
22						No. Nodes	10	
23								
24								
25								
26								
27	No. Edges		18			Create tables		Solve
28	Maximum flow		14000					
29								

Figure I.4. *An example of a spreadsheet for maximal flows*

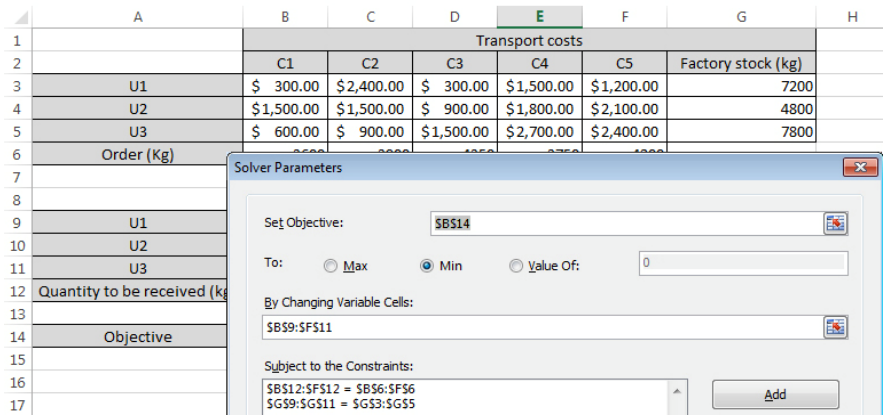


Figure I.5. *Calculating transport costs using the Microsoft Excel solver*

– *Linear programming* also requires the use of the solver in order to process the *simplex*. In this exercise you will learn how to create a spreadsheet that will formalize the inequations of the constraints of a PL problem as well as the economic function, followed by configurating the solver in order to find the optimal solution.

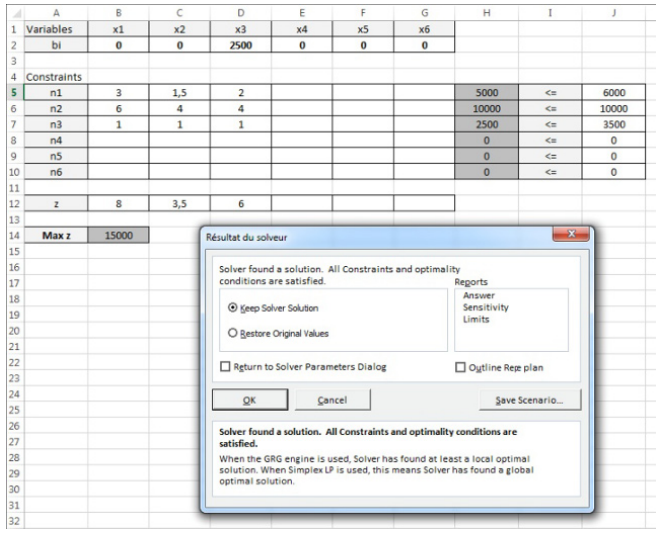


Figure I.6. *An example of linear programming, spreadsheet and solver*

Secondly, the spreadsheet will also make it possible to create *dashboards* implementing complex *pivot tables* that will work with one or a number of databases.

Client category	(All)						
Net margins	**Designation**						
VENDOR	**Product A**	**Product B**	**Product C**	**Product D**	**Product E**	**Product F**	**Grand Total**
Degeorges R.	$ -	$1,126.40	$ 512.00	$ 307.20	$ 307.20	$ 460.80	$ 2,713.60
Dupont V.	$ 204.80	$ 614.40	$ 460.80	$ 716.80	$ 256.00	$ 307.20	$ 2,560.00
Durant V.	$ 768.00	$ 204.80	$1,433.60	$ 51.20	$ 102.40	$ 512.00	$ 3,072.00
Fabre D.	$ 358.40	$ 256.00	$ -	$ 204.80	$1,075.20	$ 358.40	$ 2,252.80
Felin G.	$ 512.00	$ 460.80	$ -	$ 256.00	$ 768.00	$ -	$ 1,996.80
Marchand M.	$ 716.80	$ -	$ 204.80	$1,126.40	$ 409.60	$ 716.80	$ 3,174.40
Martin C.	$ 614.40	$1,024.00	$1,280.00	$1,075.20	$ 870.40	$ 460.80	$ 5,324.80
Pizarelli B.	$ 1,024.00	$ 102.40	$ 256.00	$1,433.60	$1,280.00	$ 716.80	$ 4,812.80
Richard T.	$ 153.60	$ 204.80	$ 409.60	$ 614.40	$ 512.00	$1,024.00	$ 2,918.40
Grand Total	**$ 4,352.00**	**$ 3,993.60**	**$ 4,556.80**	**$ 5,785.60**	**$ 5,580.80**	**$ 4,556.80**	**$ 28,825.60**

Figure I.7. *A pivot table mixing numbered and graphic data*

Within project management, we will set up a design and manufacturing plan for a machine-tool by integrating the different tasks, the resources, the costs, the creation of dashboards, reports and monitoring. We will see in detail the Gantt chart type displays and the Méthode des potentiels Métra (MPM) network, plus the Work Breakdown Structure (WBS) codification, margin calculation and the management of the over-use of resources. All of these different studies will employ the principles developed in Chapter 5 of the first volume of this series, which dealt specifically with scheduling.

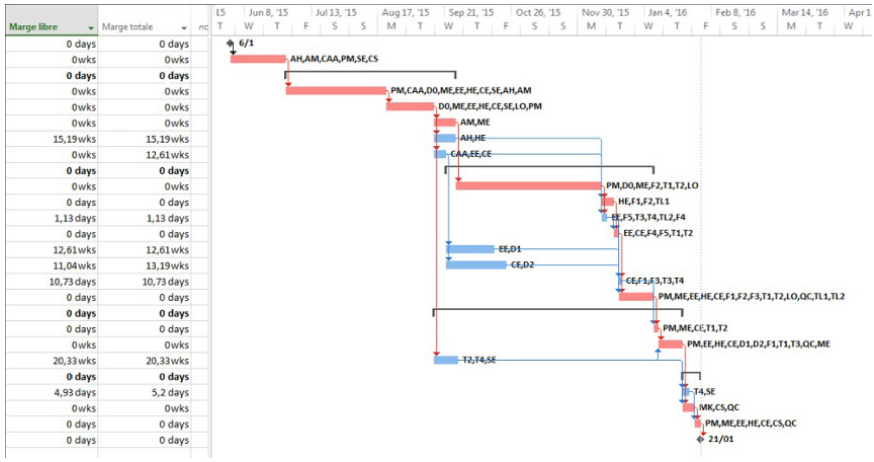


Figure I.8. *A design and manufacturing plan for a machine-tool within Microsoft Project*

Chapter 4 will focus on a particular field that is highly complex, *road traffic management*. We will examine several problems linked to the circulation of vehicles in a range of situations and contexts, at different levels, while using various programs.

Several examples will be given for each of the five applications being studied:

– a traffic jam simulator;

– an editor-simulator of traffic flow in a model incorporating junctions and traffic lights;

– an optimization simulator for an intersection managed by traffic lights;

– an editor-simulator for multi-lane road networks, integrating several kinds of vehicles, with the management of traffic lights;

– a multi-method general simulator featuring a library dedicated to road traffic management.

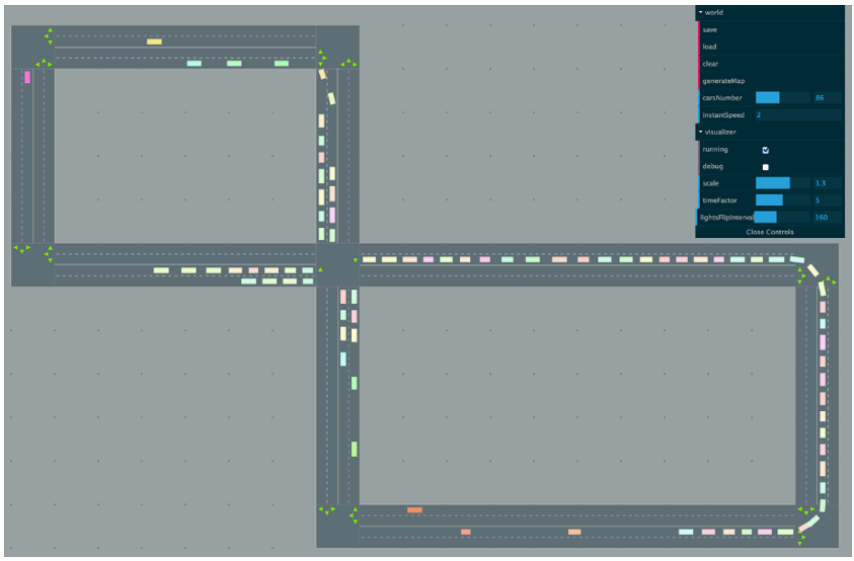


Figure I.9. *A simple road network with its intersection and traffic lights*

For each of these, we will develop *scenarios* with various different constraints in order to get an overview of the functionalities and potentials available for processing and analyzing traffic flows in circulation conditions depending on the structure of the network, the topography of the terrain, the *concentration* of vehicles, the type of vehicle, the signals, the number of traffic routes, the behavior of drivers and so on.

1

Operational Research Using a Spreadsheet

1.1. Foreword

In this chapter, I will present various possible ways of using Microsoft Excel for solving classical problems linked to operational research.

The version that I use is part of the Microsoft Office 2013 Suite. Most of the exercises shown can easily be adapted for other spreadsheets provided they have similar functions.

1.2. Dynamic programming

Here, we will examine a problem we first encountered in section 4.2.3 of the first volume of this series, the famous knapsack problem (KP).

I will present a solution here based on a spreadsheet linked to two procedures written in Visual Basic Application (VBA).

To begin with, we must first create the table in Figure 1.1 in a spreadsheet.

Once the input has been carried out, place the following formulae in the indicated cells:

- `E1: =COUNTA(B4:K4)`, calculates the number of objects available;
- `B24: =TOTAL(B23:T23)`, calculates the total value of the objects;
- now save your table;

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– switch to VBE, create a module for your project (DEVELOPER tab, VISUAL BASIC icon, right click on the project file, INSERT then MODULE);

– open the module that has just been created, normally MODULE 1 and input the following lines of code:

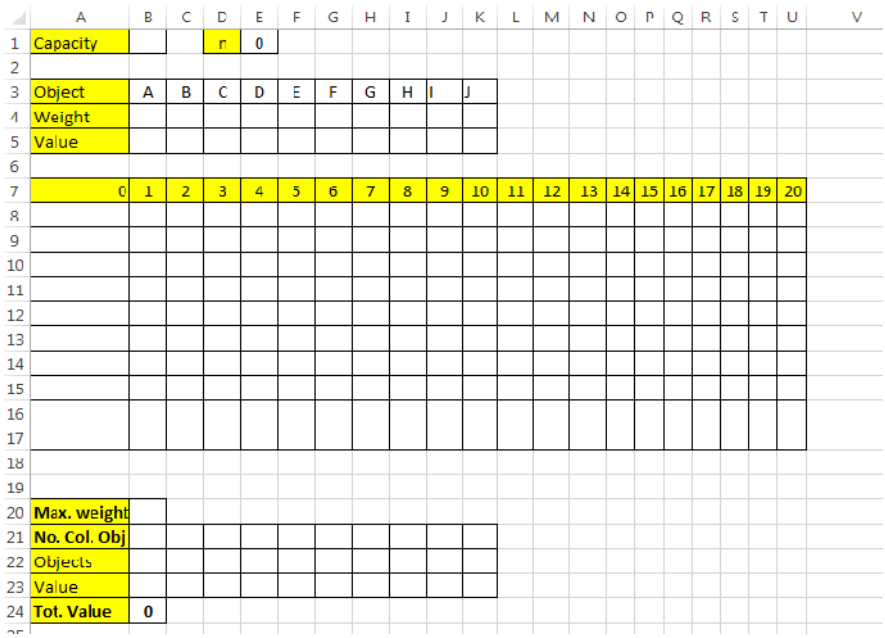


Figure 1.1. *The table to be created in the spreadsheet*

```
Sub Clear()↲
    'Clears the contents of the initial table↲
    rep = MsgBox("Do you wish to clear the tables'
contents to begin a new calculation", vbYesNo,
"Clear")↲
    If rep = vbYes Then↲
        Range("B1").ClearContents↲
        Range("B3:K5").ClearContents↲
        Range("A8:U17").ClearContents↲
        Range("B20:K23").ClearContents↲
    End If↲
End Sub↲
↲
Sub Knapsack()↲
```

```
    rep = MsgBox("Have you entered the capacity and
values in the table above to begin a new calculation
?", vbYesNo, "Calcul")↲
    If rep = vbNo Then Exit Sub↲
    'Declaration of variables and tables↲
    Dim i, j, m1, m2 As Integer↲
    'Table of weights↲
    Dim p() As Integer↲
    'Table of values↲
    Dim v() As Integer↲
    Dim c As Integer↲
    'Allocation of the capacity to the variable c↲
    c = Cells(1, 2)↲
    Dim n As Integer↲
    'Allocation of the number of objects to the
variable n↲
    n = Cells(1, 5)↲
    ReDim p(n)↲
    ReDim v(n)↲
    'Objects matrix↲
    Dim table() As Integer↲
    ReDim table(n, c)↲
↲
    'Reading object weight↲
    For i = 1 To n↲
        p(i) = Cells(4, i + 1)↲
    Next↲
↲
    'Reading object weight↲
    For j = 1 To n↲
       v(j) = Cells(5, j + 1)↲
    Next↲
↲
    Initializing the table, setting its content to 0↲
    For j = 0 To c↲
        table(0, j) = 0↲
    Next↲
↲
  'Constructing and filling the matrix↲
    For i = 1 To n↲
        For j = 0 To c↲
            If j >= p(i) Then↲
                m1 = table(i - 1, j)↲
```

```
                m2 = table(i - 1, j - p(i)) + v(i)↲
                If m1 > m2 Then table(i, j) = m1 Else
table(i, j) = m2↲
            Else↲
                table(i, j) = table(i - 1, j)↲
            End If↲
            Cells(7 + i, j + 1) = table(i, j)↲
        Next↲
    Next↲
↲
  'Reading objects↲
    Dim ob(8) As String↲
    For u = 1 To n↲
       ob(u) = Cells(3, u + 1)↲
    Next↲
↲
  'Further reallocation of variables↲
    i = n↲
    j = c↲
↲
    'Determining maximal weight↲
    Dim k, m As Integer↲
    m = 2↲
    For k = c To 0 Step -1↲
        If table(i, j) = table(i, j - 1) Then j = j -
1↲
    Next↲
    Cells(20, 2) = j↲
↲
    'Obtaining the list of objects in the table of
results↲
    While i > 0 And j > 0↲
        If table(i, j) <> table(i - 1, j) Then↲
            j = j - p(i)↲
            Cells(22, m) = ob(i)↲
            Cells(23, m) = v(i)↲
            Cells(21, m) = i↲
            i = i - 1↲
            m = m + 1↲
        Else↲
            i = i - 1↲
        End If↲
    Wend↲
End Sub↲
```

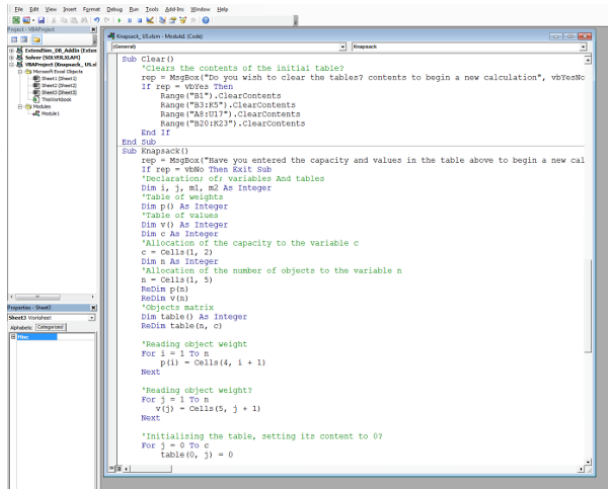


Figure 1.2. *The VBA code window in VBE attached to Module 1 of the project*

To launch these two procedures, `Clear()` and `Knapsack()`, create two buttons by inserting two forms to which you will assign each of the two macros (right click on form then ASSIGN MACRO…). Your spreadsheet should look like the one in Figure 1.3.

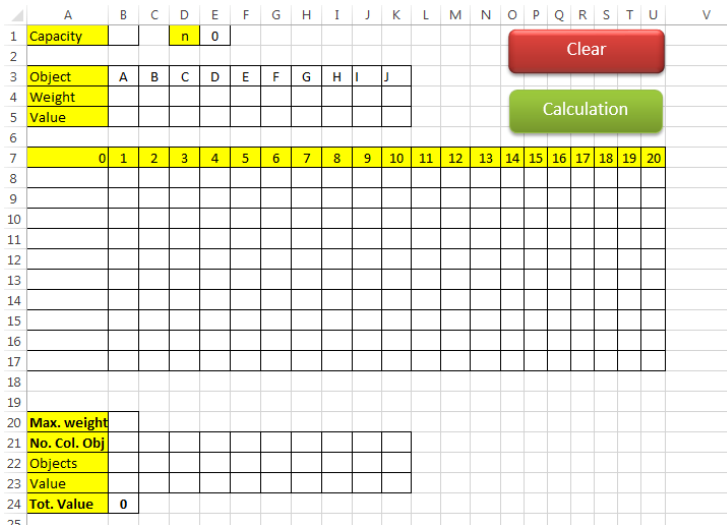


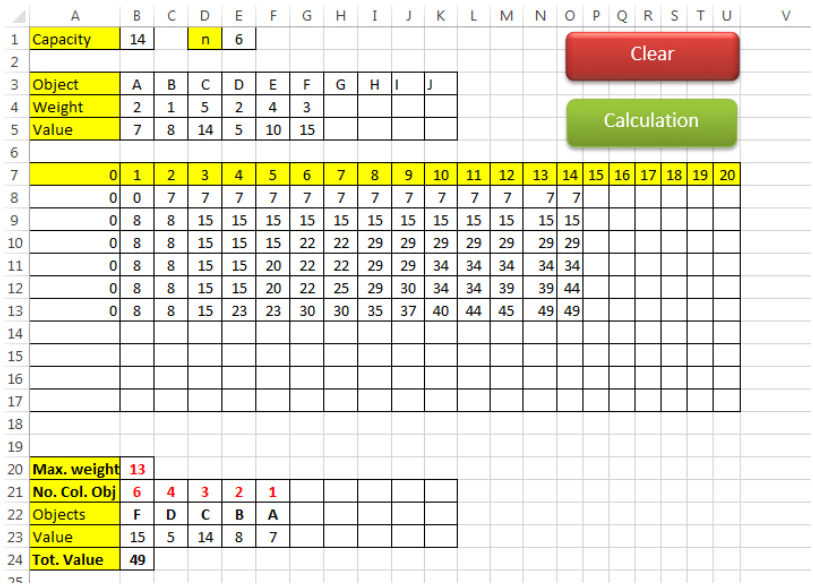
Figure 1.3. *An accounting spreadsheet containing two (Delete and Calculate) procedure buttons (macros)*

In order to use the KP calculation, all you need to do is click on the CLEAR button to erase any calculation that has already been carried out and to delete the calculated contents.

Secondly, you should input the data in the upper table (`B1` and `B3` to `K5`).

For the final stage, click on the CALCULATE button to launch the calculation and to show the results.

COMMENT 1.1.– In the spreadsheet that we have just created, you can manage up to 10 objects. Nothing will stop you from increasing this number by making the necessary modifications to the tables and the relevant VBA procedures.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	Capacity	14		n	6																	
2																						
3	Object	A	B	C	D	E	F	G	H	I	J											
4	Weight	2	1	5	2	4	3															
5	Value	7	8	14	5	10	15															
6																						
7	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
8	0	0	7	7	7	7	7	7	7	7	7	7	7	7	7							
9	0	8	8	15	15	15	15	15	15	15	15	15	15	15	15							
10	0	8	8	15	15	15	22	22	29	29	29	29	29	29	29							
11	0	8	8	15	15	20	22	22	29	29	34	34	34	34	34							
12	0	8	8	15	15	20	22	25	29	30	34	34	39	39	44							
13	0	8	8	15	23	23	30	30	35	37	40	44	45	49	49							
14																						
15																						
16																						
17																						
18																						
19																						
20	Max. weight	13																				
21	No. Col. Obj	6	4	3	2	1																
22	Objects	F	D	C	B	A																
23	Value	15	5	14	8	7																
24	Tot. Value	49																				

Figure 1.4. *The example of paragraph 4.2.3.3 calculated. The results can be seen in the bottom table*

1.3. Scheduling

In this section, I will describe two possible ways of using the Excel spreadsheet:

– as a method for calculating the critical path and the duration of the project based on a calculation using a matrix (double entry table);

– for creating a simple Gantt chart using a precedence table.

1.3.1. *Critical path calculation matrix*

Using a Microsoft Excel spreadsheet containing a matrix constructed around several calculation formulae, we will be able to determine the critical path and the duration of a project (see section 5.8 of Volume 1 [REV 17a]).

The table shown is limited to a PERT chart with at most 10 points. It can easily be adapted to a larger number of lines and columns by applying the same logic in order to create the missing calculation formulae.

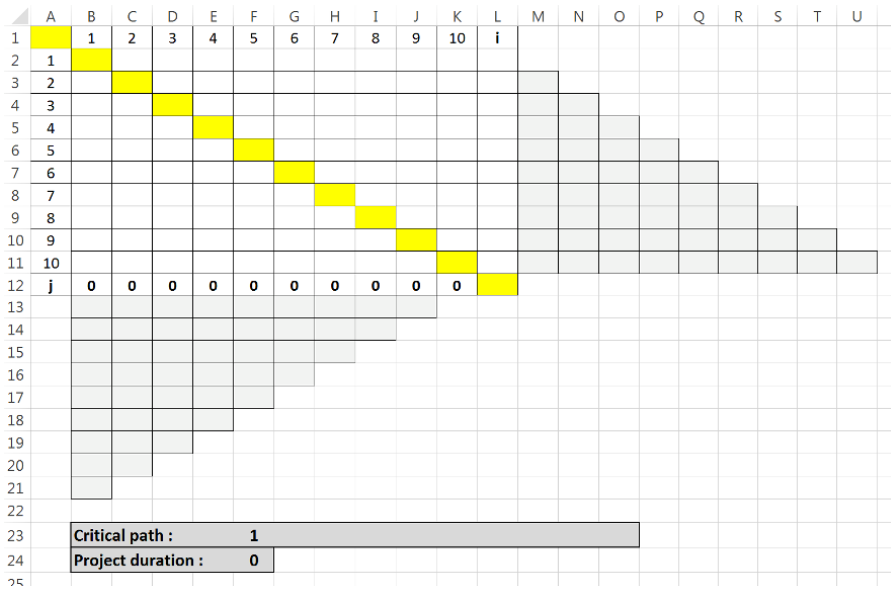
In order to present and explain how this spreadsheet functions, we will re-use Exercise 2 from section 5.14.2 of Volume 1 [REV 17a], whose matrix is shown in Table 1.1.

	1	2	3	4	5	6	7	8	i
1		2							0
2			10	6	8				2
3					0				12
4					4	10	18		8
5							5		12
6							4		18
7								4	26
8									30
j	0	2	21	8	21	22	26	30	

Table 1.1. *The double entry matrix from Exercise 2*

Let's now create an accounting spreadsheet like the one in Figure 1.5.

We can see that the matrix created is designed for 10 points. The grayed-out areas will contain calculation formulae as well as the columns from the beginning for the earliest start and latest end dates *i* and *j*.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1		1	2	3	4	5	6	7	8	9	10	i									
2	1																				
3	2																				
4	3																				
5	4																				
6	5																				
7	6																				
8	7																				
9	8																				
10	9																				
11	10																				
12	j	0	0	0	0	0	0	0	0	0	0										
13																					
14																					
15																					
16																					
17																					
18																					
19																					
20																					
21																					
22																					
23		Critical path :				1															
24		Project duration :				0															
25																					

Figure 1.5. *The table to be created in the spreadsheet*

Let's begin with the section on the right, in Figure 1.6. Here, you can see the formulae to be inputted (only cells `L3` and `P6` are shown – the others follow the same pattern).

	J	K	L	M	N	O	P
9		10	i				
			0				
			=IF(COUNTA(D2:D3)=0,L2,M3)	=I2+C2			
			=IF(MAX(M4:S4)=0,L3,MAX(M4:S4))	=IF(D3<>"",L3+D3,"")	=IF(D2<>"",L2+D2,"")		
			=IF(MAX(M5:S5)=0,L4,MAX(M5:S5))	=IF(E4<>"",L4+E4,"")	=IF(E3<>"",L3+E3,"")	=IF(E2<>"",L2+E2,"")	
			=IF(MAX(M6:S6)=0,L5,MAX(M6:S6))	=IF(F5<>"",L5+F5,"")	=IF(F4<>"",L4+F4,"")	=IF(F3<>"",L3+F3,"")	=IF(F2<>"",L2+F2,"")

Figure 1.6. *The section on the right with the calculation formulae to be inputted*

We will comment on these formulae that fit with the calculation technique described in section 5.8.3 of Volume 1. All they do is automate the approach:

– `M3: =L2+C2`, adds the earliest start date for the first task to the first value encountered;

– L3: =IF(COUNTA(D2:D3)=0,L2,M3), checks for the absence of a value in D2 and D3, if the value is absent, it displays the previous earliest start date, which is L2, otherwise nothing is displayed;

– M4: =IF(D3<>"",L3+D3,""), checks for the presence of a value in D3 and in this case effects the sum L3+D3, otherwise nothing is displayed;

– N4: =IF(D2<>"",L2+D2,""), identical to the previous test for cell D2. The other group of grey cells, from M5 to U11, behaves in the same way, by taking account of each of the values present or absent in the column in question;

– L4: =IF(MAX(M4:S4)=0,L3,MAX(M4,S4)), checks the maximal value calculated in the column (the result of the calculations placed in cells M4 to S4). If it is equal to 0, no values will have been calculated, we can therefore assume that all the points have been reached, in which case the last value calculated from the beginning to the end should be copied, which is L3, otherwise the maximum is displayed. The same goes for the other formulae placed from L5 to L11 with the corresponding cells.

Let's now look at the lower part, cells K12 to B21. As was the case with the previous example, only a few formulae are shown. The others follow the same pattern:

– K12: =L11, returns to the last value in the column of earliest start dates;

– C13: =IF(D3<>"",D12-D3,""), checks if the cell located below the diagonal is empty and if it is not, calculates the difference with the corresponding cell, which is D12-D3, otherwise nothing is displayed. This calculation is identical for all the other cells in the grey zone if the cell references are changed to obtain the appropriate result (see Figure 1.7);

– C12: =IF(MIN(C13:C21)=0,D12,MIN(C13:C21)), checks the minimal value calculated in the column (the result of the calculations in cells C13 to C20). If it is equal to 0, no values will have been calculated, we can therefore assume that the vertex has not been reached, in which case the last value calculated for the latest end date is copied, which is cell D12, otherwise the minimum is displayed. The same goes for the other formulae located in D12 to J12 with the corresponding cells;

– B12: =MIN(B13:B21), calculates the minimal value from zone B13 to B21, to display the latest end date of the first vertex in the graph.

	A	B	C	D
10	9			
11	10			
12	j	=MIN(B13:B21)	=IF(MIN(C13:C21)=0,D12,MIN(C13:C21))	=IF(MIN(D13:D21)=0,E12,MIN(D13:D21))
13		=IF(C2<>"",C12-C2,"")	=IF(D3<>"",D12-D3,"")	=IF(E4<>"",E12-E4,"")
14		=IF(D2<>"",D12-D2,"")	=IF(E3<>"",E12-E3,"")	=IF(F4<>"",F12-F4,"")
15		=IF(E2<>"",E12-E2,"")	=IF(F3<>"",F12-F3,"")	=IF(G4<>"",G12-G4,"")
16		=IF(F2<>"",F12-F2,"")	=IF(G3<>"",G12-G3,"")	=IF(H4<>"",H12-H4,"")

	I	J	K
	=IF(MIN(I13:I14)=0,J12,MIN(I13:I14))	=IF(MIN(J13)=0,K12,J13)	=L11
	=IF(J9<>"",J12-J9,"")	=IF(K10<>"",K12-K10,"")	
	=IF(K9<>"",K12-K9,"")		

Figure 1.7. *The cells located below the CPM matrix with their formulae*

We will now concern ourselves with find the critical path through the graph node numbers. The length of the project is associated with the last value for the earliest beginning, `L11`:

– `F23: =IF(B12=L2,B1,"")`, tests if cell `B12` is equal to cell `B2` and displays the node number located in `B1`. This formula is not compulsory, it can simply be replaced by `=L2`, since the first node is always in the critical path, except in specific cases;

– `G23: =IF(MAX(M3)<>0,IF(C12=L3,C1,""),"")`, we find two interlinked tests. The first verifies that M3 is different to 0, if this was not the case, this would mean that the current node does not belong to the critical path and nothing would be displayed. If `M3` is different to 0 then we check that `C12` is equal to its corresponding cell, `L3`, on the diagonal in the matrix and the node number `C1` is displayed, otherwise nothing is displayed;

– `H23: =IF(MAX(M4:N4)<>0,IF(D12=L4;D1,""),"")`, identical to the above, but with a zone of `M4` to `N4` to test the maximum;

– the same principle is then applied for the cells from `I23` to `O23` with the corresponding cell references.

	A	B	C	D	E	F	G	H
16		=IF(F2<>"",F12-F2,"")	=IF(=IF	=IF	=IF	=IF(J6<>"",J12-J6,"")	=IF(K7<>"","",K12-K7)	
17		=IF(G2<>"",G12-G2,"")	=IF(=IF	=IF	=IF	=IF(K6<>"",K12-K6,""		
18		=IF(H2<>"",H12-H2,"")	=IF(=IF	=IF				
19		=IF(H2<>"",H12-H2,"")	=IF(=IF					
20		=IF(J2<>"",J12-J2,"")	=IF(					
21		=IF(K2<>"",K12-K2,"")						
22								
23		Critical path :				=IF(B12=L2,B1,"")	=IF(MAX(M3)<>0,IF(C12=L3,C1,""),"")	=IF(MAX(M4:N4)<>0,IF(D12=L4,D1,""),"")
24		Project duration :				=L11		
25								

Figure 1.8. *Calculating the critical field and display showing the duration*

See Figure 1.9 for the results obtained after inputting the figures from the table referred to earlier.

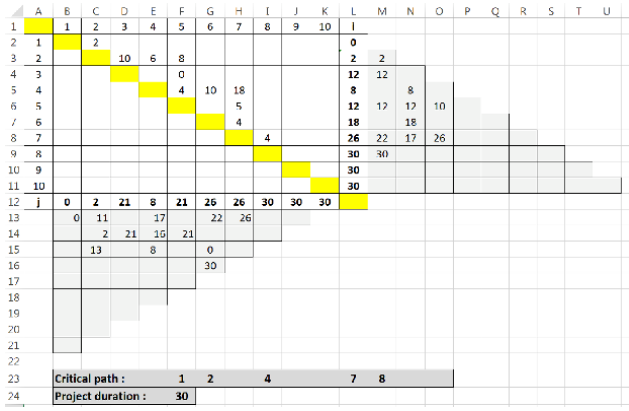


Figure 1.9. *Spreadsheet with all cells filled in the matrix. Note the values of I (earliest start) and j (latest end) as well as the length of the project and the critical path that passes through nodes: 1, 2, 4, 7 and 8*

1.3.2. *Classic Gantt chart*

In order to create this chart, we will use the public address system exercise dealt with in section 5.5 of Volume 1. In the precedence table (Table 1.2) only the columns for task and duration (in minutes) have been retained with the addition of two new columns, start and end.

Task	Start	Duration	End
A	0	120	120
B	120	20	145
C	120	15	140
D	120	20	140
E	140	10	155
F	140	15	155
G	155	25	180
H	140	20	180
I	180	15	195

Table 1.2. *Tasks, starts, durations and ends for the sonorization exercise*

This table is inserted into a Microsoft Excel spreadsheet and we then add a variance column that will calculate the difference between "End" and "Start" (in the cell `E2: =D2-B2`) in order to obtain the matrix in Figure 1.10.

	A	B	C	D	E	F
1	**Task**	**Start**	**Duration**	**End**	**Variation**	
2	A	0	120	120	120	
3	B	120	20	145	25	
4	C	120	15	140	20	
5	D	120	20	140	20	
6	E	140	10	155	15	
7	F	140	15	155	15	
8	G	155	25	180	25	
9	H	140	20	180	40	
10	I	180	15	195	15	
11						
12						

Figure 1.10. *The matrix corresponding to the task table with each of its columns*

Next, select the table, then carry out the following group of operations:

– INSERT tab, CHARTS toolbar, select INSERT A BAR CHART, select STACKED BARS in 2D BAR (Figure 1.11);

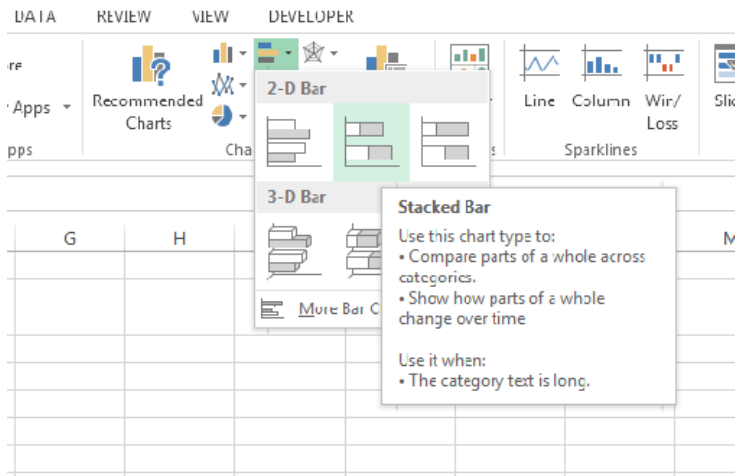


Figure 1.11. *Microsoft Excel: insert a 2D STACKED BAR CHART*

– finally, move the graph and resize it (Figure 1.12);

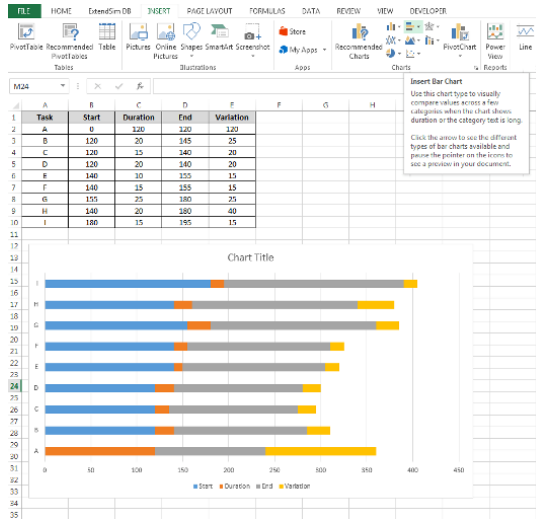


Figure 1.12. *The resized graph, positioned under the matrix*

– click on the y-axis;

– right-click, select FORMAT AXIS (Figure 1.13);

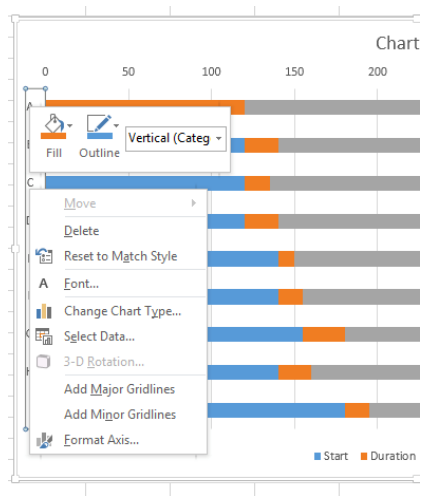


Figure 1.13. *The contextual menu (right click) to format the axis*

– in the FORMAT AXIS window, select CATEGORIES IN REVERSE ORDER (Figure 1.14);

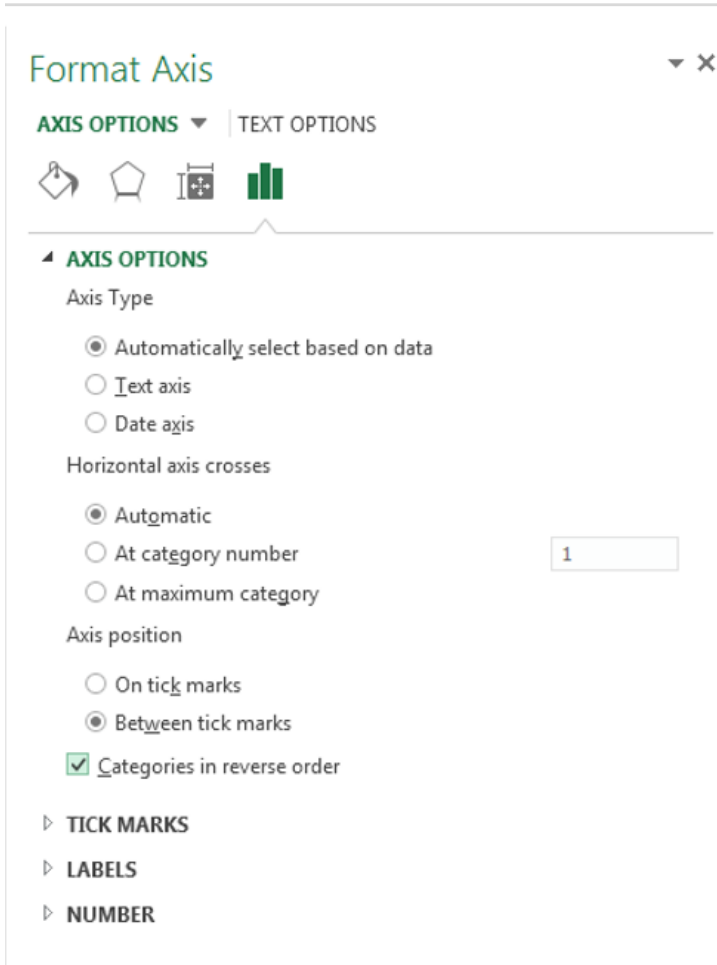


Figure 1.14. *The window for configuring the axis in Microsoft Excel 2013, including the checkbox: values in reverse order (in axis options)*

– click on the x axis to select it;

– in the FORMAT AXIS window, open drop-down LABELS and select HIGH in LABEL POSITION;

– enter 10 and 5 respectively in AXIS OPTIONS as MAJOR and MINOR UNITS (Figure 1.15);

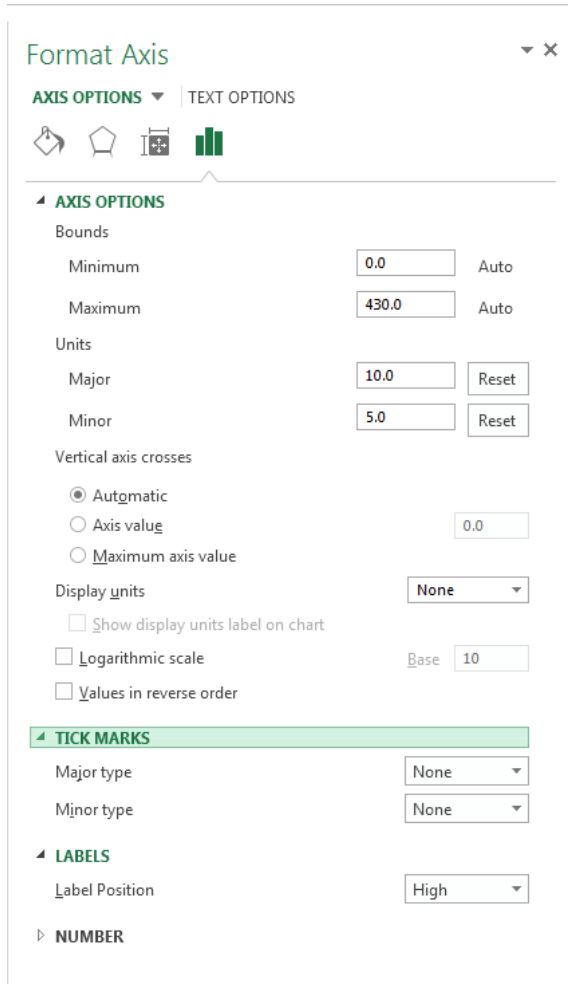


Figure 1.15. *Configuring axes (10 and 5) and labels (high)*

– right click on the middle of the graph and click on SELECT DATA;

– a window for selecting a data source will open. Tick "Duration" and "End Date" (you can also remove these using the DELETE button) then validate by clicking the OK button (Figure 1.16);

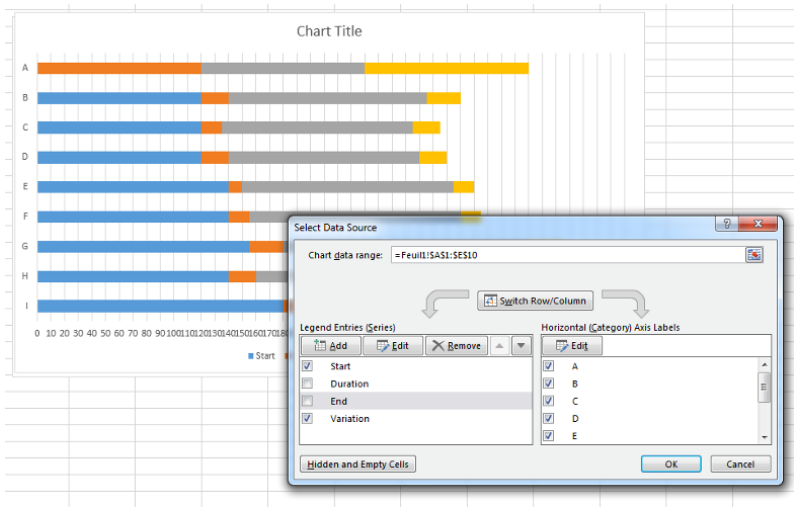


Figure 1.16. *The fields "length" and "end" selected in the window displaying the data source*

– click on the legend and delete it (press DEL or backspace on Mac);

– right click on the "Start" bar on the graph, specify NO OUTLINE and NO FILL by clicking on the corresponding icons (OUTLINE and FILL) in the pop-up tool bar (Figure 1.17);

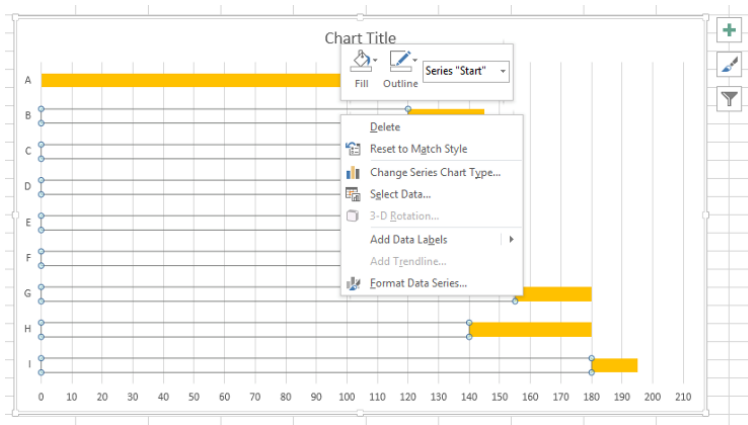


Figure 1.17. *The menu and the pop-up tool bar, obtained by right-clicking on the "Start" bar. Note the tools OUTLINE and FILL above the menu*

– double-click on the title to change it and type “Outdoor public address system”;

– to finish, save your work (Figure 1.18).

Task	Start	Duration	End	Variation
A	0	120	120	120
B	120	20	145	25
C	120	15	140	20
D	120	20	140	20
E	140	10	155	15
F	140	15	155	15
G	155	25	180	25
H	140	20	180	40
I	180	15	195	15

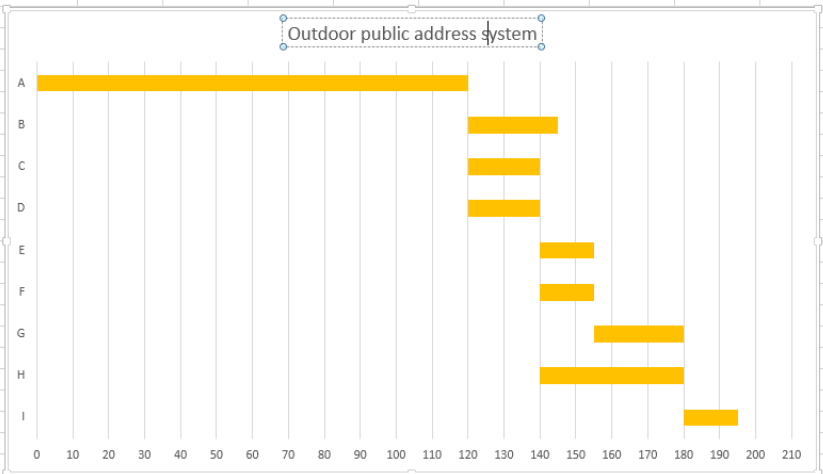


Figure 1.18. *The finished Gantt chart and its associated table in a Microsoft Excel 2013 spreadsheet*

1.3.3. *Gantt chart with a calendar*

In cases where dates have to be managed according to a calendar that can show workdays and holidays, we must consider excluding the latter from the project timeline.

Table 1.3 gives an example involving these conditions.

Installing an air conditioning system (simplified agenda) (see Table 1.3).

Task	Appointment	Duration (days)	Previous
A	Needs analysis (electrical equipment, piping, fittings, coolant gas and various other components)	1	–
C	Order and delivery of electrical equipment	5	A
D	Order and delivery of the group exchanger and diffusers	8	A
E	Order and delivery of coolant gas	4	A
F	Assembly, installation and laying of the group exchanger	2	D
G	Installation and laying of diffusers	4	D
H	Laying and connecting pipes	2	B, F, G
I	Electrical connection	1	C, F, G
J	Filling the installation, pressurization and clean-up	1	E, H
K	Switching on, testing installation and tuning	1	H, I, J
L	Tidying up the work site	1	K

Table 1.3. *The precedence table for the installation of an air-conditioning system*

For this second exercise, we will consider the project start date as being Monday March 2nd 2015.

We will begin by entering a table in Microsoft Excel similar to the one shown in Figure 1.19. The dates for the start and the end have been calculated in a standard way using a PERT or MPM type method (the MPM chart is shown in Figure 1.20).

	A	B	C	D	E	F
1	**Project start date :**		**03/02/15**			
2						
3	**Task**	**Start**	**Duration**	**End**	**Variation**	
4	**A**	**03/02/15**	**1**	**03/03/15**	**1**	
5	B	03/03/15	10	**03/17/15**	14	
6	C	03/03/15	5	**03/10/15**	7	
7	**D**	**03/03/15**	**8**	**03/13/15**	**10**	
8	E	03/03/15	4	**03/09/15**	6	
9	F	03/11/15	2	**03/13/15**	2	
10	**G**	**03/11/15**	**4**	**03/17/15**	**6**	
11	**H**	**03/15/15**	**2**	**03/17/15**	**2**	
12	I	03/15/15	1	**03/16/15**	1	
13	**J**	**03/17/15**	**1**	**03/18/15**	**1**	
14	**K**	**03/18/15**	**1**	**03/19/15**	**1**	
15	**L**	**03/19/15**	**1**	**03/20/15**	**1**	

Figure 1.19. *The table to be created in Microsoft Excel (here the critical tasks are in gray and in bold)*

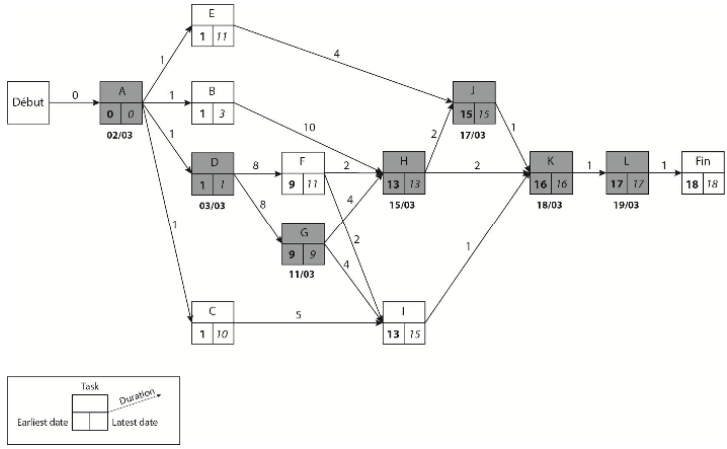


Figure 1.20. *The MPM chart corresponding to the project: installation of an air conditioning system*

In the cell `D4` (End), we have the formula `=B4+C4`, that we will fill downward as far as `D15`.

In the cell `E4` (Variance), we have the formula `=D4-B4`, that we will fill downward as far as `E15`.

It should be noted that the end dates do not take into account a week where only the days from Monday to Friday will be workdays. To compensate for this we can replace the formula, located in `D4`, by `=SERIES.WORK.DAY(B4;C4)`. This gives the table shown in Figure 1.21.

	A	B	C	D	E	F
1	**Project start date :**		**03/02/15**			
2						
3	**Task**	**Start**	**Duration**	**End**	**Variation**	
4	**A**	**03/02/15**	**1**	**03/03/15**	**1**	
5	B	03/03/15	10	**03/17/15**	14	
6	C	03/03/15	5	**03/10/15**	7	
7	**D**	**03/03/15**	**8**	**03/13/15**	**10**	
8	E	03/03/15	4	**03/09/15**	6	
9	F	03/11/15	2	**03/13/15**	2	
10	**G**	**03/11/15**	**4**	**03/17/15**	**6**	
11	**H**	**03/15/15**	**2**	**03/17/15**	**2**	
12	I	03/15/15	1	**03/16/15**	1	
13	**J**	**03/17/15**	**1**	**03/18/15**	**1**	
14	**K**	**03/18/15**	**1**	**03/19/15**	**1**	
15	**L**	**03/19/15**	**1**	**03/20/15**	**1**	

Figure 1.21. *The table recalculated for workdays*

In order to properly display the graph, it will be necessary to change the format of the dates in the columns “Start” and “End” by replacing the date format with the standard format:

– select cells `B4` to `B15`, then, while holding down CTRL, cells `D4` to `D15`;

– right click, FORMAT CELLS…, NUMBER tab, GENERAL category.

This gives the number of days since 1st January 1900 in each of the cells.

	A	B	C	D	E	F
1	**Project start date :**		**03/02/15**			
2						
3	**Task**	**Start**	**Duration**	**End**	**Variation**	
4	**A**	**42065**	**1**	**42066**	**1**	
5	B	42066	10	**42080**	14	
6	C	42066	5	**42073**	7	
7	**D**	**42066**	**8**	**42076**	**10**	
8	E	42066	4	**42072**	6	
9	F	42074	2	**42076**	2	
10	**G**	**42074**	**4**	**42080**	**6**	
11	**H**	**42078**	**2**	**42080**	**2**	
12	I	42078	1	**42079**	1	
13	**J**	**42080**	**1**	**42081**	**1**	
14	**K**	**42081**	**1**	**42082**	**1**	
15	**L**	**42082**	**1**	**42083**	**1**	

Figure 1.22. *The “Start” and “End” columns in STANDARD format*

Next, select the table, then carry out the following operations:

– INSERT tab, CHARTS toolbar, scroll down to BAR, select STACKED BAR in 2D BAR;

– move the chart and resize it;

– click on the y-axis;

– right click, select Excel US syntax;

– in the FORMAT AXIS window, tick CATEGORIES IN REVERSE ORDER;

– click on the x-axis to select it;

– in the FORMAT AXIS window, click on the icon in the shape of a bar chart;

– enter 42065 (the value of the cell B4, for 03/02/2015, the start date for the project) in AXIS OPTIONS as MINIMUM;

– next, enter 7 and 1 respectively as MAJOR and MINOR UNITS;

– pull down LABELS and select HIGH in LABEL POSITION;

– pull down NUMBER, select DATE in CATEGORY then *3/14/2001 in TYPE;

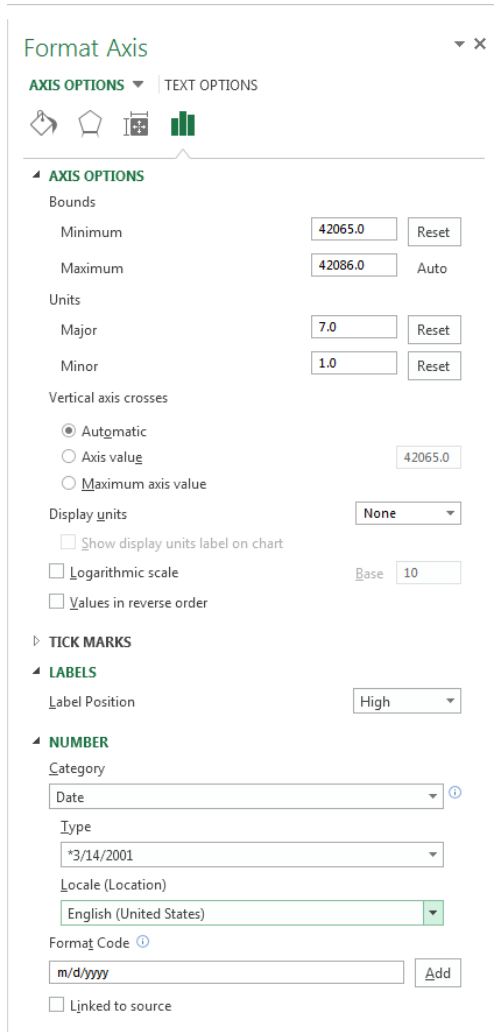


Figure 1.23. *AXIS OPTIONS, LABELS and NUMBER*

– in the FORMAT AXIS window, click on cross-shaped icon (to the left of the bar chart);

– pull down ALIGNMENT and enter -45° in the field CUSTOM ANGLE in order to pivot the dates on the x-axis;

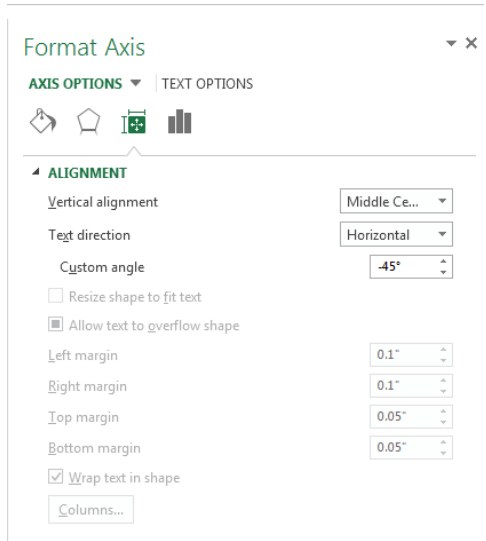


Figure 1.24. *AXIS OPTIONS, ALIGNMENT -45°*

– right click on the bottom of the chart and click on SELECT DATA;

– a 'Data Sources' window will open. Tick "Duration" and "End" (you can also remove these using the DELETE button) then validate by clicking the OK button;

– click on the legend and delete it (hold down DEL or back space on a Mac);

– right click on the "Start" bar on the chart, specify NO OUTLINE and NO FILL by clicking on the corresponding icons (OUTLINE AND FILL) in the pop-up tool bar;

– right click on a date on the x axis, ADD A MINOR GRIDLINE;

– double click on the title to change it and type "Installing an air conditioning system";

– next, repeat a date format for the "Start" and "End" columns;

– to finish, save your work;

– you can change the colors of the chart by putting, for example, critical tasks in a different color.

	A	B	C	D	E
1	**Project start date :**		**03/02/15**		
2					
3	**Task**	**Start**	**Duration**	**End**	**Variation**
4	**A**	**03/02/15**	**1**	**03/03/15**	**1**
5	B	03/03/15	10	**03/17/15**	14
6	C	03/03/15	5	**03/10/15**	7
7	**D**	**03/03/15**	**8**	**03/13/15**	**10**
8	E	03/03/15	4	**03/09/15**	6
9	F	03/11/15	2	**03/13/15**	2
10	**G**	**03/11/15**	**4**	**03/17/15**	**6**
11	**H**	**03/15/15**	**2**	**03/17/15**	**2**
12	I	03/15/15	1	**03/16/15**	1
13	**J**	**03/17/15**	**1**	**03/18/15**	**1**
14	**K**	**03/18/15**	**1**	**03/19/15**	**1**
15	**L**	**03/19/15**	**1**	**03/20/15**	**1**

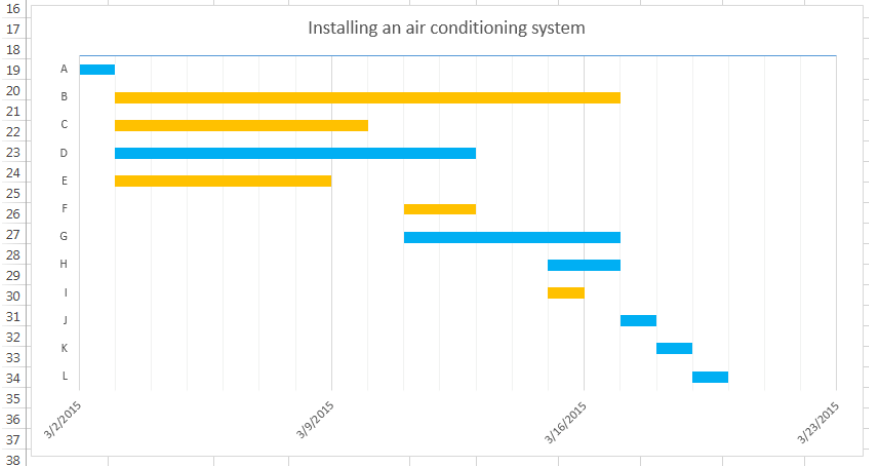


Figure 1.25. *The finished table and chart corresponding to the Gantt chart for the project*

The exercises for creating a Gantt chart that have previously been examined can be adapted for larger projects. The table will be larger but the principles and the practical tasks remain the same.

1.4. Maximal flows

In order to calculate the maximal flow available in a network between the source and the sink, we will use the Excel solver alongside two VBA procedures and a spreadsheet. In the solution shown here, the number of edges is limited to 25 and the number of vertices is limited to 20.

Begin by creating the spreadsheet in Figure 1.26.

	A	B	C	D	E	F	G	H	I
1	**From**	**To**	**Flow**	**Capacity**		**Nodes**	**Net Flow**	**Supply/Demand**	
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22						No. Nodes	0		
23									
24									
25									
26									
27	No. Edges		0						
28	**Maximum flow**								
29									

Figure 1.26. *The spreadsheet to be created in Microsoft Excel*

Next, enter the following calculations:

– `G2: =IF(F2="","",SUMIF(From,F2,Flow)-SUMIF(To,F2, Flow))`, if the cell in the column "Nodes" is empty then nothing is displayed; if not the difference is calculated: the total of the flows equal to F2 in the column "From" – the total of the flows equal to F2 in the column "To". This will determine the net flow;

– "From" and "To" are cell ranges that will be named later using a VBA procedure;

– Copy `G2` downward as far as cell `G21`;

– `C27: =COUNTA(A2:A26)`, counts the number of edges;

– `G22: =COUNTA(F2:F21)`, counts the number of vertices;

– `C28: =G2`, displays the maximal flow;

– then save your table;

– switch to VBE, create a module for your project (DEVELOPER tab, VISUAL BASIC icon, right click on the project file, INSERT then MODULE);

– open the module that has just been created, ordinarily MODULE 1 and input the following lines of code:

```
Sub Create_tables()↲
Dim CountArc, CountNodes As String↲
  'Clear tables↲
    'If  click on No then clear otherwise quit↲
    If MsgBox("Do you wish to clear the table content?",
vbYesNo, "Clear") = vbYes Then↲
    'Clears the cell content↲
        Range("A2:D26,F2:F21,H3:H21").Select↲
        Selection.ClearContents↲
        'Deletes the cell background color↲
        Range("A2:D26,F2:G21,H3:H21").Select↲
        Selection.Interior.ColorIndex = 0↲
        Range("C28").Select↲
        'Relaunch automatic sheet recalculation↲
        Application.Calculation =
xlCalculationAutomatic↲
    Else↲
        Exit Sub↲
    End If↲
  'Name and color allocation↲
    CountArc = InputBox("How many edges does your graph
have?", "Number of edges")↲
    'If click on Cancel then quit↲
    If CountArc = "" Then Exit Sub↲
    Range(Cells(2, 1), Cells(1 + CountArc, 1)).Name =
"From"↲
    Range(Cells(2, 1), Cells(1 + CountArc,
3)).Interior.ColorIndex = 40↲
    Range(Cells(2, 2), Cells(1 + CountArc, 2)).Name =
"To"↲
    Range(Cells(2, 2), Cells(1 + CountArc,
3)).Interior.ColorIndex = 44↲
    Range(Cells(2, 3), Cells(1 + CountArc, 3)).Name =
"Flow"↲
    Range(Cells(2, 3), Cells(1 + CountArc,
3)).Interior.ColorIndex = 36↲
    Range(Cells(2, 4), Cells(1 + CountArc, 4)).Name =
"Capacity"↲
    Range(Cells(2, 4), Cells(1 + CountArc,
4)).Interior.ColorIndex = 27↲
```

```
    CountNode = InputBox("How many vertices does your
graph have?", "Number of nodes")↵
    'If click on Cancel then quit↵
    If CountNode = "" Then Exit Sub↵
    Range(Cells(2, 6), Cells(1 + CountNode, 6)).Name =
"Node"↵
    Range(Cells(2, 6), Cells(1 + CountNode,
6)).Interior.ColorIndex = 17↵
    Range(Cells(3, 7), Cells(CountNode, 7)).Name =
"NetFlow"↵
    Range(Cells(2, 7), Cells(1 + CountNode,
7)).Interior.ColorIndex = 37↵
    Range(Cells(3, 8), Cells(CountNode, 8)).Name =
"SupplyDemand"↵
    Range(Cells(3, 8), Cells(CountNode,
8)).Interior.ColorIndex = 8↵
    MsgBox ("You can now enter your" & CountArc & " arcs
with their capacity in the FROM and TO column. Then
enter the list of your " & CountNode & "nodes in NODES
column.")↵
    Range(Cells(3, 8), Cells(CountNode, 8)) = 0↵
End Sub↵
↵

'Launch the solver to find the solution↵
Sub Resolve()↵
    'Reset solver to zero↵
    SolverReset↵
    'Defining solver parameters↵
    SolverOk SetCell:="$C$28", MaxMinVal:=1, ValueOf:=0,
ByChange:="$C$2:$C$19", _↵
        Engine:=2, EngineDesc:="Simplex LP"↵
    SolverDelete CellRef:="$C$2:$C$19", Relation:=1,
FormulaText:="Capacity"↵
    SolverOk SetCell:="$C$28", MaxMinVal:=1, ValueOf:=0,
ByChange:="$C$2:$C$19", _↵
        Engine:=2, EngineDesc:="Simplex LP"↵
    SolverAdd CellRef:="$C$2:$C$19", Relation:=1,
FormulaText:="Capacity"↵
    SolverOk SetCell:="$C$28", MaxMinVal:=1, ValueOf:=0,
ByChange:="$C$2:$C$19", _↵
        Engine:=2, EngineDesc:="Simplex LP"↵
    SolverDelete CellRef:="$G$3:$G$10", Relation:=2,
FormulaText:="SupplyDemand"↵
    SolverOk SetCell:="$C$28", MaxMinVal:=1, ValueOf:=0,
ByChange:="$C$2:$C$19", _↵
        Engine:=2, EngineDesc:="Simplex LP"↵
```

```
    SolverAdd CellRef:="$G$3:$G$10", Relation:=2,
FormulaText:="SupplyDemand"↲
    SolverOk SetCell:="$C$28", MaxMinVal:=1, ValueOf:=0,
ByChange:="$C$2:$C$19", _↲
        Engine:=2, EngineDesc:="Simplex LP"↲
    SolverOk SetCell:="$C$28", MaxMinVal:=1, ValueOf:=0,
ByChange:="$C$2:$C$19", _↲
        Engine:=2, EngineDesc:="Simplex LP"↲
    'Launch automatic calculation of results by the
solver↲
    SolverSolve (True)↲
End Sub↲
```

In order to launch these two procedures, `Create_tables()` and `Resolve()`, create two buttons by inserting two forms to which you will assign each of the two macros (right click on form then ASSIGN a MACRO). Your spreadsheet should look like the one in Figure 1.27.

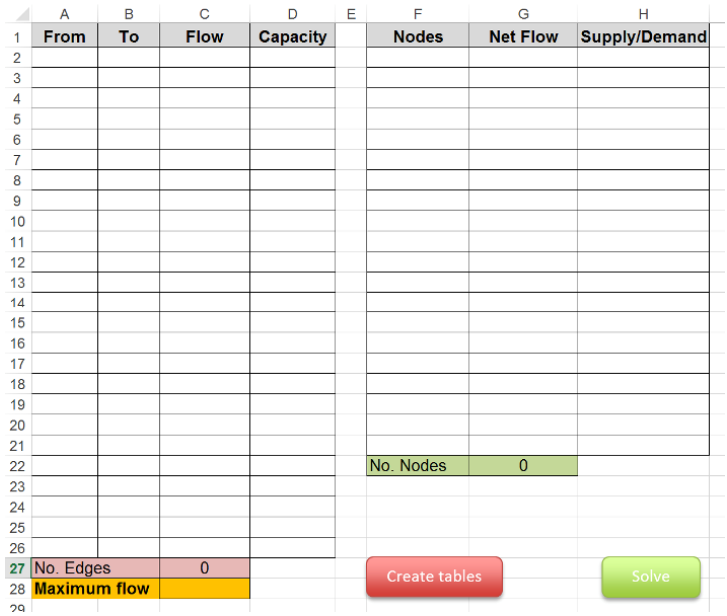


Figure 1.27. *The spreadsheet with its two buttons ("Create tables" and "Solve")*

In order to use the calculation of maximal flows, all you need to do is click on the CREATE TABLES button to destroy any calculation that has already been carried out and delete the calculated contents. Two dialogue boxes will be displayed

one after the other asking you how many edges you want followed by the number of vertices in your graph.

Enter the data in the table on the left by mentioning, for each arc, the peak of departure in the column “From” and its vertice (node) of arrival in the column “To” followed by its capacity in the column “Capacity”.

Now add the flows. I would advise entering the minimal value of the capacity for all of the flows.

Next, input all the vertices in the table on the right, in the “Vertices” column, beginning with the source (ordinarily S) and ending with the sink (ordinarily T). The order for the other vertices is irrelevant.

It should be noted that the entry fields have been colored in order to make it easier to input data.

Lastly, click on the SOLVE button to begin the calculation of the solution by the solver and to display the results.

In Figure 1.28, I re-use the data from Exercise 1 in Chapter 6 (Volume 1, section 6.5.1), and you can see all edges and their capacities (18), all the vertices (10) and the starting flow, which is 2000.

	From	To	Flow	Capacity
1	S	P1	2000	10000
2	S	P2	2000	8000
3	S	P3	2000	6000
4	P1	P2	2000	4000
5	P1	R1	2000	6000
6	P2	R1	2000	4000
7	P2	R2	2000	2000
8	P2	R3	2000	2000
9	P3	P2	2000	4000
10	P3	R3	2000	6000
11	R1	R2	2000	4000
12	R1	R4	2000	6000
13	R2	R4	2000	4000
14	R2	R5	2000	3000
15	R3	R2	2000	6000
16	R3	R5	2000	2000
17	R4	T	2000	12000
18	R5	T	2000	4000
19				
20				
21				
22				
23				
24				
25				
26	No. Edges		18	
27	Maximum flow		6000	
28				

	Nodes	Net Flow	Supply/Demand
1	S	6000	
2	P2	0	0
3	P3	2000	0
4	R1	0	0
5	R2	-2000	0
6	R3	0	0
7	R4	-2000	0
8	R5	-2000	0
9	P1	2000	0
10	T	-4000	
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21	No. Nodes	10	

Create tables Solve

Figure 1.28. *The data from Exercise 1 in Chapter 6 entered into the spreadsheet*

Figure 1.29 shows the result of the calculation launched by clicking on the SOLVE button.

	A	B	C	D	E	F	G	H
1	From	To	Flow	Capacity		Nodes	Net Flow	Supply/Demand
2	S	P1	6000	10000		S	14000	
3	S	P2	8000	8000		P2	0	0
4	S	P3	0	6000		P3	0	0
5	P1	P2	0	4000		R1	0	0
6	P1	R1	6000	6000		R2	0	0
7	P2	R1	4000	4000		R3	0	0
8	P2	R2	2000	2000		R4	0	0
9	P2	R3	2000	2000		R5	0	0
10	P3	P2	0	4000		P1	0	0
11	P3	R3	0	6000		T	-14000	
12	R1	R2	4000	4000				
13	R1	R4	6000	6000				
14	R2	R4	4000	4000				
15	R2	R5	2000	3000				
16	R3	R2	0	6000				
17	R3	R5	2000	2000				
18	R4	T	10000	12000				
19	R5	T	4000	4000				
20								
21								
22						No. Nodes	10	
23								
24								
25								
26								
27	No. Edges		18			Create tables		Solve
28	Maximum flow		14000					
29								

Figure 1.29. *The solution from exercise 1 with the set of results displayed*

1.5. Transport model

There are a variety of logistical problems in transport: often, you need to standardize distances, the costs and the constraints for supplying customers.

Below, you will find two classic examples that will be solved using the Microsoft Excel solver.

Using this as a basis, it will be easy to use each of these solutions to adapt them to your own problems.

1.5.1. *Customer delivery*

A railway company has to transport two batches of palletized products from two departure stations (GD1 and GD2) to three destination stations (GA1, GA2 and GA3) spread out across France. The goods will pass through intermediary marshalling yards (GT1, GT2, GT3, GT4 and GT5).

The number of pallets available in the outgoing stations and the storage capacities of the end stations are known, as are the transport capacities of the inter-station railway lines.

Table 1.4 groups together the shared information for each station.

Pallet flow										
→	**DS1**	**DS2**	**MY1**	**MY2**	**MY3**	**MY4**	**MY5**	**ES1**	**ES2**	**ES3**
Pallets available	**105**	**75**								
DS1		–	60	45	36	–	–	–	–	–
DS2	–		–	18	66	–	-	–	–	–
MY1	–	–	–	30	–	45	–	–	–	–
MY2	–	–	–	–	–	–	–	30	45	45
MY3	–	–	–	–	–		66	–	–	–
MY4	–	-	–	–	–	–	–	21	30	–
MY5	–	-	–	–	–		–	–	30	30
Storage capacities of the arrival stations								**45**	**45**	**60**

Table 1.4. *Summary of palletized product batch flow*

If we examine the problem in greater detail, we notice that there is a problem involving maximal flow with constraints being exceeded.

We will tackle this problem by using a simple double-entry table as well as the solver.

First, create and fill a spreadsheet, the table shown in Figure 1.30.

1													
2													
3		DS : Departure station				MY : Marshalling yard				ES : End station		Flow :	0
4													
5		S	DS1	DS2	MY1	MY2	MY3	MY4	MY5	ES1	ES2	ES3	T
6	S	0	105	75	0	0	0	0	0	0	0	0	0
7	DS1	0	0	0	60	45	36	0	0	0	0	0	0
8	DS2	0	0	0	0	18	66	0	0	0	0	0	0
9	MY1	0	0	0	0	30	0	45	0	0	0	0	0
10	MY2	0	0	0	0	0	0	0	0	30	45	45	0
11	MY3	0	0	0	0	0	0	0	66	0	0	0	0
12	MY4	0	0	0	0	0	0	0	0	21	30	0	0
13	MY5	0	0	0	0	0	0	0	0	0	30	30	0
14	ES1	0	0	0	0	0	0	0	0	0	0	0	45
15	ES2	0	0	0	0	0	0	0	0	0	0	0	45
16	ES3	0	0	0	0	0	0	0	0	0	0	0	60
17	T	0	0	0	0	0	0	0	0	0	0	0	0
18													

Figure 1.30. *The table to be created in a Microsoft Excel spreadsheet*

All of the data from the statement is shown here. For this purpose, the table has an S column and a T column, which represent the source and the sink, thus formalizing the number of pallets available at the departure station (DS1: 105 and DS: 75) and the storage capacity of the end stations (ES1: 45, ES2: 45 and ES3: 60).

Below the first table, add a second like the one shown in Figure 1.31.

18													
19													
20		S	DS1	DS2	MY1	MY2	MY3	MY4	MY5	ES1	ES2	ES3	T	Total
21	S	0	0	0	0	0	0	0	0	0	0	0	0	
22	DS1	0	0	0	0	0	0	0	0	0	0	0	0	0
23	DS2	0	0	0	0	0	0	0	0	0	0	0	0	0
24	MY1	0	0	0	0	0	0	0	0	0	0	0	0	0
25	MY2	0	0	0	0	0	0	0	0	0	0	0	0	0
26	MY3	0	0	0	0	0	0	0	0	0	0	0	0	0
27	MY4	0	0	0	0	0	0	0	0	0	0	0	0	0
28	MY5	0	0	0	0	0	0	0	0	0	0	0	0	0
29	ES1	0	0	0	0	0	0	0	0	0	0	0	0	0
30	ES2	0	0	0	0	0	0	0	0	0	0	0	0	0
31	ES3	0	0	0	0	0	0	0	0	0	0	0	0	0
32	T	0	0	0	0	0	0	0	0	0	0	0	0	
33	Total		0	0	0	0	0	0	0	0	0	0		
34														

Figure 1.31. *The second table positioned below the first*

It will be filled as indicated below:

– line 33 will contain the total of each of the columns;

– in cell C33, enter : =TOTAL(C21:C32);

– next, copy this formula down to cell L33;

– column N will contain the total of each of the lines;

– in Cell N22, enter : =TOTAL(B22:M22);

– next, reproduce this below until N31;

– in cell N3, enter the total of the wells to maximize : =TOTAL(B31:M31);

– launch the solver, DATA tab, SOLVER tool in the tool ribbon. If it is not visible, consult Appendix 1 of this volume to begin its installation;

– configure the solver as shown in Figure 1.32;

– SET OBJECTIVE : $N$3;

– BY CHANGING VARIABLE CELLS : $B$21:$M$32;

– SUBJECT TO THE CONSTRAINTS : $B$21:$M$32<=$B$6:$M$17;

– SUBJECT TO THE CONSTRAINTS : $C$33:$L$33=$N$22:$N$31;

– Tick the box MAKE UNCONSTRAINTED VARIABLES NON-NEGATIVE

– SELECT A SOLVING METHOD : Simplex PL;

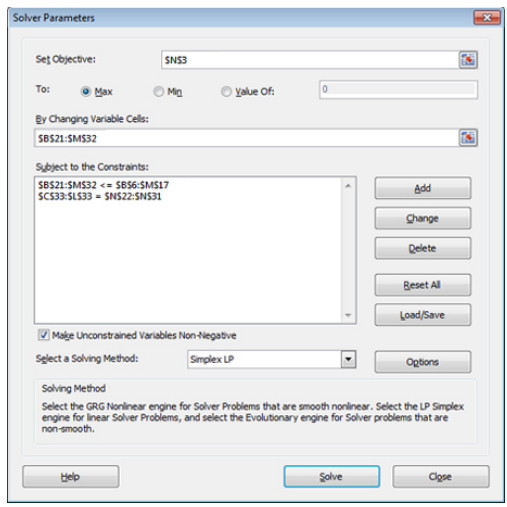


Figure 1.32. *Configuring the solver*

– Next, click on the bottom SOLVE. In a few moments, the solver will display the result window;

– You will then be able to SAVE SOLVER SOLUTION or RESET INITIAL VALUES (to start again) by ticking the appropriate box and clicking on the OK button.

This will give you the values from Figure 1.33 in the second table that will specify the number of pallets to be transported between each of the points, taking all restrictions into account.

	S	DS1	DS2	MY1	MY2	MY3	MY4	MY5	ES1	ES2	ES3	T	Total
S	0	105	45	0	0	0	0	0	0	0	0	0	
DS1	0	0	0	57	45	3	0	0	0	0	0	0	105
DS2	0	0	0	0	18	27	0	0	0	0	0	0	45
MY1	0	0	0	0	30	0	27	0	0	0	0	0	57
MY2	0	0	0	0	0	0	0	0	30	33	30	0	93
MY3	0	0	0	0	0	0	0	30	0	0	0	0	30
MY4	0	0	0	0	0	0	0	0	15	12	0	0	27
MY5	0	0	0	0	0	0	0	0	0	0	30	0	30
ES1	0	0	0	0	0	0	0	0	0	0	0	45	45
ES2	0	0	0	0	0	0	0	0	0	0	0	45	45
ES3	0	0	0	0	0	0	0	0	0	0	0	60	60
T	0	0	0	0	0	0	0	0	0	0	0	0	
Total		105	45	57	93	30	27	30	45	45	60		

Figure 1.33. *The results calculated by the solver*

You can see that the total number of pallets arriving at the destination does not exceed 150 (45+45+60), ensuring that the storage capacity of the arrival stations is not exceeded.

1.5.2. *Minimum-cost transport*

In this type of problem, the aim is to transport goods at a minimal cost while taking into account restrictions such as customer demand and warehouse storage capacity.

Let's consider three factories (U1, U2 and U3) located in France who wish to deliver to their clients (C1 to C5) spread out across Europe. The transport costs (per ton: 1,000 kg) are specified in Table 1.5.

Factory stock	C1	C2	C3	C4	C5
U1	$300.00	$2,400.00	$300.00	$1,500.00	$1,200.00
U2	$1,500.00	$1,500.00	$900.00	$1,800.00	$2,100.00
U3	$600.00	$900.00	$1,500.00	$2,700.00	$2,400.00

Table 1.5. *Transport costs between factories and customers*

In terms of stock, each factory has a volume of available product estimated at being 7,200 kg for U1, 4,800 kg for U2 and 7,800 kg for U3.

The five clients want the following quantities: C1, 3,600 kg; C2, 3,900 kg; C3, 4,350 kg; C4, 3,750 kg and C5, 4,200 kg.

It is now necessary to define what mass of product each of the three factories must send to each of the five customers in order to meet demand, taking into account the stock available and minimizing transport costs.

First, create the two tables in Figure 1.34 in a Microsoft Excel spreadsheet.

	A	B	C	D	E	F	G	H
1		Transport costs						
2		C1	C2	C3	C4	C5	Factory stock (kg)	
3	U1	$ 300.00	$2,400.00	$ 300.00	$1,500.00	$1,200.00	7200	
4	U2	$1,500.00	$1,500.00	$ 900.00	$1,800.00	$2,100.00	4800	
5	U3	$ 600.00	$ 900.00	$1,500.00	$2,700.00	$2,400.00	7800	
6	Order (Kg)	3600	3900	4350	3750	4200		
7								
8		C1	C2	C3	C4	C5	Quantity to be send	
9	U1						0	
10	U2						0	
11	U3						0	
12	Quantity to be received (kg)	0	0	0	0	0		
13								
14	Objective	0						
15								
16								
17								

Figure 1.34. *The two tables for calculating costs*

Next, apply the following operations:

– in cell `B12`, enter the calculation : `=TOTAL(B9:B11)`;

– copy this formula to the right as far as F12;

– in G9, enter : =TOTAL(B9:F9);

– next, copy this total downwards as far as G11;

– in cell B14, we will define the calculation objective for the solver. This is the total that we must minimize;

– enter : =SUMPRODUCT(B3:F5;B9:F11);

– open the solver, DATA tab, SOLVER tool in the ribbon. If it is not visible, consult Appendix 1 for the installation procedure;

– enter the parameters as shown in Figure 1.35;

– SET OBJECTIVE: $B$14;

– BY CHANGING VARIABLE CELLS: $B$9:$F$11;

– SUBJECT TO THE CONSTRAINTS: $B$12:$F$12=$B$6:$F$6;

– SUBJECT TO THE CONSTRAINTS: $G$9:$G$11=$G$3:$G$5;

– Tick MAKE UNCONSTRAINED VARIABLES NON-NEGATIVE;

– SELECT A SOLVING METHOD: Simplex PL;

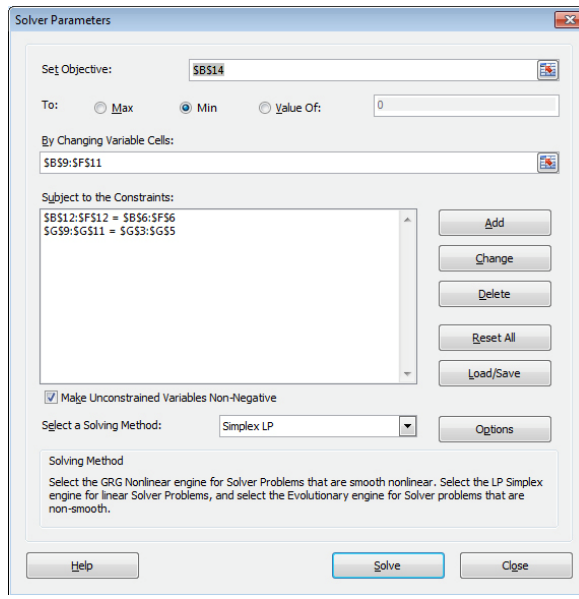


Figure 1.35. *Configuration of the solver*

– next, click on the SOLVE button and wait a few seconds;

– a window will open. You will then have the option to SAVE THE SOLVER SOLUTION or RESET TO ORIGINAL VALUES (to start again) by ticking the appropriate box and clicking on the OK button.

The lower table displays the quantities to be dispatched to each of the factories of each of the customers. We can see that the restrictions relating to customer orders and to factory stocks have been taken into account.

	A	B	C	D	E	F	G	H
1		Transport costs						
2		C1	C2	C3	C4	C5	Factory stock (kg)	
3	U1	$ 300.00	$2,400.00	$ 300.00	$1,500.00	$1,200.00	7200	
4	U2	$1,500.00	$1,500.00	$ 900.00	$1,800.00	$2,100.00	4800	
5	U3	$ 600.00	$ 900.00	$1,500.00	$2,700.00	$2,400.00	7800	
6	Order (Kg)	3600	3900	4350	3750	4200		
7								
8		C1	C2	C3	C4	C5	Quantity to be send	
9	U1	0	0	3300	0	3900	7200	
10	U2	0	0	1050	3750	0	4800	
11	U3	3600	3900	0	0	300	7800	
12	Quantity to be received (kg)	3600	3900	4350	3750	4200		
13								
14	Objective	19755000						
15								

Figure 1.36. *The results obtained from using the solver*

1.6. Linear programming

I will now show you how to use the Microsoft Excel solver to solve classical linear programming problems that would be solved on paper using a simplex.

We will create a spreadsheet capable of holding six constraints relating to six variables, by responding to maximization and minimization requests.

It will be very easy to increase the amount of data to manage by applying the same calculation formulae on a larger table.

1.6.1. *Creating a calculation table*

Build and fill the table in Figure 1.37 in a spreadsheet, then carry out the following:

	A	B	C	D	E	F	G	H	I	J	K
1	Variables	x1	x2	x3	x4	x5	x6				
2	bi										
3											
4	Constraints										
5	n1							0	<=		
6	n2							0	<=		
7	n3							0	<=		
8	n4							0	<=		
9	n5							0	<=		
10	n6							0	<=		
11											
12	z	20	30								
13											
14	Max z	0									
15											

Figure 1.37. *The table that will host our future linear programs*

– In cell H5, enter the formula: `=TOTALPRODUCT (B5:G5;$B$2:$G$2)`. This formula carries out the total of the products between the cells in line 5 (constraint n°1) and line 2 (b_i);

– Next, copy this formula downward as far as H10;

– In cell B14, enter the formula : `=TOTALPRODUCT(B12:G12;B2:G2)`. This formula calculates the total of the products between the cells in line 12 (z) and line 2 (b_i);

– Save your spreadsheet.

1.6.2. *Entering data*

To fill in our table, we will re-use the example from Chapter 8 (Volume 1, section 8.3.2), which has three constraints and the following profit, z:

$$\begin{cases} 3x_1 + 1{,}5x_2 + 2x_3 \le 6000 \\ 6x_1 + 4x_2 + 4x_3 \le 10000 \\ x_1 + x_2 + x_3 \le 3500 \end{cases}$$

$$z = 8x_1 + 3{,}5x_2 + 6x_3$$

Enter this data in your spreadsheet in order to obtain the table in Figure 1.38.

	A	B	C	D	E	F	G	H	I	J	K
1	Variables	x1	x2	x3	x4	x5	x6				
2	bi										
3											
4	Constraints										
5	n1	3	1,5	2				0	<=	6000	
6	n2	6	4	4				0	<=	10000	
7	n3	1	1	1				0	<=	3500	
8	n4							0	<=		
9	n5							0	<=		
10	n6							0	<=		
11											
12	z	8	3,5	6							
13											
14	Max z	0									
15											

Figure 1.38. *The data from the example, entered into our table*

COMMENT 1.2.– The indicators of inequality (<=) located in column I in our table are only given as an illustrative example – they are not relevant in the calculation.

1.6.3. *Using the solver*

Open the solver, DATA tab, SOLVER tool in the ribbon. If it is not visible, consult Appendix 1 for the installation procedure.

Complete the different fields for the solver:

– SET OBJECTIVE : `$B$14`;

– Click on the option MAX (for this example we are dealing with an example of maximization) ;

– BY CHANGING VARIABLE CELLS : `$B$2:$G$2`;

– SUBJECT TO THE CONSTRAINTS : `$B$2:$G$2>=0`; `$H$10<=$I$10`; `$H$5<=$J$5` ; `$H$6<=$J$6`; `$H$7<=$J$7` ; `$H$8<=$J$8` ; `$H$9<=$J$9`;

COMMENT 1.3.– The constraints are not all necessary in our example, but the solver has been configured by default in order to solve a problem involving six inequalities.

– Tick the box : MAKE UNCONSTRAINED VARIABLES NON-NEGATIVE;

– SELECT A SOLVING METHOD: Simplex PL;

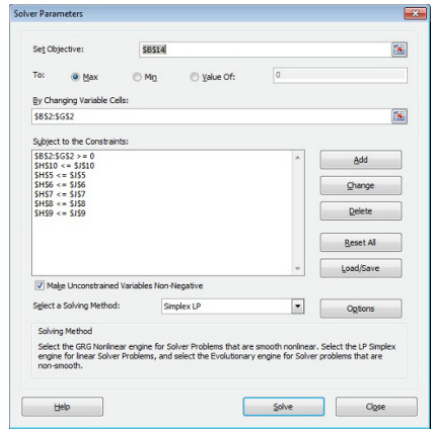


Figure 1.39. *The different parameters entered in the solver dialogue window*

– click on the SOLVE button;

– after a few moments the results will be displayed in the table and the SOLVER RESULTS window will be displayed.

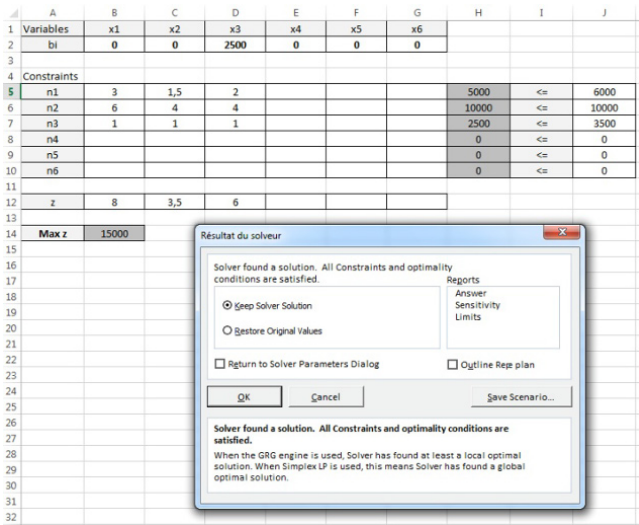


Figure 1.40. *Calculated results and the SOLVER RESULTS window*

The results found in Chapter 8 (Volume 1, section 8.3.7) are confirmed: *z = 15000; x1=0; x2=0 and x3 = 2500.*

2

Dashboards, Spreadsheets and Pivot Tables

2.1. Spreadsheets: a versatile tool

Since their creation, in the early 1970s, spreadsheets have become an essential tool in business and even outside of the professional sphere. Today, how many people manage their bank accounts using one?

In this chapter, I will introduce you to the possibilities available with any proper spreadsheet using pivot tables that can provide quality decision aid dashboards.

The following examples do not hinge on basic functionalities but on advanced usage, with functions that are often not particularly well known, but which are highly effective in terms of processing data and saving precious time for decision-makers. I will therefore make the assumption that the reader has the requisite experience for creating simple pivot tables.

In the previous chapter of this volume, I made extensive use of spreadsheets (Microsoft Excel) but here I would like to focus more specifically on the handling of data from a Database Management System (DBMS) or a spreadsheet that itself constitutes a database for creating sophisticated dashboards or contingency tables[1].

In order to carry out these studies, I made the decision to use the spreadsheet Microsoft Excel 2013, but the examples given can easily be adapted to other

1 A concept introduced by the British mathematician and statistician Karl Pearson in 1904 that involves crossing two characters from a population and presenting their combined result.

Modeling and Simulation of Logistics Flows 2: Dashboards, Traffic Planning and Management,
First Edition. Jean-Michel Réveillac.

versions or other spreadsheets featuring the pivot table concept such as, among others, the OpenOffice “DataPilot” or the FreeOffice “Pivot Tables”.

2.2. Example database

Before beginning our practical examples, we will need to create or import a sufficiently representative database in order for our various experiments to be consistent.

I would suggest creating a database with several columns grouped in a single table, created using a DBMS then imported into Microsoft Excel or entered directly into a spreadsheet.

The headings for our database will be:

– Date: the date of the sale including day, month, year – format: dd/mm/yy;

– Designation: product labeling, “Product A” to “Product F” – format: text;

– Net UP: Unit price before product tax – format: _($* #,##0.00_);

– Qty: quantity in terms of number of units – format: whole number, 0;

– Vendor: vendor name – format: text;

– Agency: location of the sales agency – format: text;

– Cat client: client category, INDV (individual), PRO (professional) – format: text;

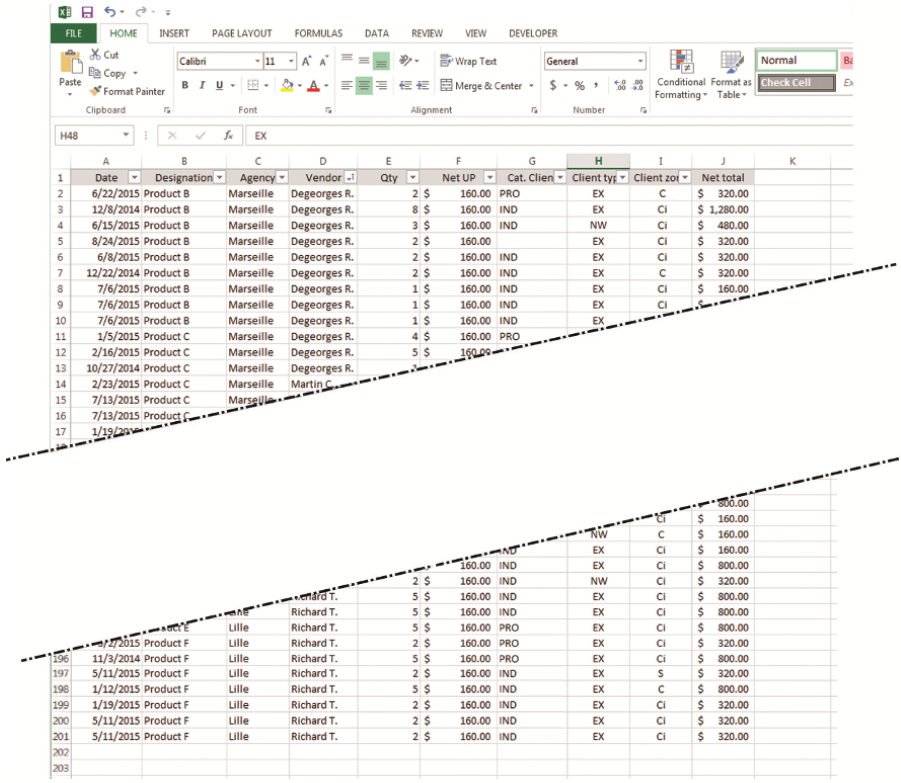
– Client type: N (new), EX (existing) – format: text;

– Client area of residence: C (city), Di (District), D (Departement), C (County), S (State), OS (Outside state) – format: text;

– Net total: quantity x unit price BT – format: ($* #,##0.00_).

Figure 2.1 shows an outline of the spreadsheet containing the database.

In order to obtain enough combinations to allow us to draw meaningful conclusions, I would advise creating a table or a chart containing at least a hundred rows (tuples or records).



	A	B	C	D	E	F	G	H	I	J	K
1	Date	Designation	Agency	Vendor	Qty	Net UP	Cat. Clien	Client typ	Client zo	Net total	
2	6/22/2015	Product B	Marseille	Degeorges R.	2	$ 160.00	PRO	EX	C	$ 320.00	
3	12/8/2014	Product B	Marseille	Degeorges R.	8	$ 160.00	IND	EX	Ci	$ 1,280.00	
4	6/15/2015	Product B	Marseille	Degeorges R.	3	$ 160.00	IND	NW	Ci	$ 480.00	
5	8/24/2015	Product B	Marseille	Degeorges R.	2	$ 160.00		EX	Ci	$ 320.00	
6	6/8/2015	Product B	Marseille	Degeorges R.	2	$ 160.00	IND	EX	Ci	$ 320.00	
7	12/22/2014	Product B	Marseille	Degeorges R.	2	$ 160.00	IND	EX	C	$ 320.00	
8	7/6/2015	Product B	Marseille	Degeorges R.	1	$ 160.00	IND	EX	Ci	$ 160.00	
9	7/6/2015	Product B	Marseille	Degeorges R.	1	$ 160.00	IND	EX	Ci		
10	7/6/2015	Product B	Marseille	Degeorges R.	1	$ 160.00	IND	EX			
11	1/5/2015	Product C	Marseille	Degeorges R.	4	$ 160.00	PRO				
12	2/16/2015	Product C	Marseille	Degeorges R.	5	$ 160.00					
13	10/27/2014	Product C	Marseille	Degeorges R.							
14	2/23/2015	Product C	Marseille	Martin C.							
15	7/13/2015	Product C	Marseille								
16	7/13/2015	Product F									
17	1/19/2015										
										$ 800.00	
									Ci	$ 160.00	
								NW	C	$ 160.00	
							IND	EX	Ci	$ 160.00	
						160.00	IND	EX	Ci	$ 800.00	
					2	$ 160.00	IND	NW	Ci	$ 320.00	
				Richard T.	5	$ 160.00	IND	EX	Ci	$ 800.00	
				Richard T.	5	$ 160.00	IND	EX	Ci	$ 800.00	
			Lille	Richard T.	5	$ 160.00	PRO	EX	Ci	$ 800.00	
196	11/3/2014	Product F	Lille	Richard T.	2	$ 160.00	PRO	EX	Ci	$ 320.00	
197	5/11/2015	Product F	Lille	Richard T.	5	$ 160.00	IND	EX	S	$ 800.00	
198	1/12/2015	Product F	Lille	Richard T.	2	$ 160.00	IND	EX	C	$ 320.00	
199	1/19/2015	Product F	Lille	Richard T.	5	$ 160.00	IND	EX	Ci	$ 800.00	
200	5/11/2015	Product F	Lille	Richard T.	2	$ 160.00	IND	EX	Ci	$ 320.00	
201	5/11/2015	Product F	Lille	Richard T.	2	$ 160.00	IND	EX	Ci	$ 320.00	
202											
203											

Figure 2.1. *Example database*

2.2.1. *Calculated field and formatting*

To begin with, we want to create a table that will synthesize the net margin that each vendor has provided for each product depending on the client category. This margin is estimated as being 32% of the net price of the sale regardless of the product.

Furthermore, it would be preferable, for ease of interpretation, to be able to quickly visualize the size of the margin in chart form.

Figure 2.2. shows the result to be obtained.

M	N	O	P	Q	R	S	T
Client category	(All)						
Net margins	Designation						
VENDOR	Product A	Product B	Product C	Product D	Product E	Product F	Grand Total
Degeorges R.	$ -	$1,126.40	$ 512.00	$ 307.20	$ 307.20	$ 460.80	$ 2,713.60
Dupont V.	$ 204.80	$ 614.40	$ 460.80	$ 716.80	$ 256.00	$ 307.20	$ 2,560.00
Durant V.	$ 768.00	$ 204.80	$1,433.60	$ 51.20	$ 102.40	$ 512.00	$ 3,072.00
Fabre D.	$ 358.40	$ 256.00	$ -	$ 204.80	$1,075.20	$ 358.40	$ 2,252.80
Felin G.	$ 512.00	$ 460.80	$ -	$ 256.00	$ 768.00	$ -	$ 1,996.80
Marchand M.	$ 716.80	$ -	$ 204.80	$1,126.40	$ 409.60	$ 716.80	$ 3,174.40
Martin C.	$ 614.40	$1,024.00	$1,280.00	$1,075.20	$ 870.40	$ 460.80	$ 5,324.80
Pizarelli B.	$ 1,024.00	$ 102.40	$ 256.00	$1,433.60	$1,280.00	$ 716.80	$ 4,812.80
Richard T.	$ 153.60	$ 204.80	$ 409.60	$ 614.40	$ 512.00	$1,024.00	$ 2,918.40
Grand Total	$ 4,352.00	$3,993.60	$4,556.80	$5,785.60	$5,580.80	$4,556.80	$28,825.60

Figure 2.2. *The dashboard to create*

We will create a simple table that can then be customized:

– create a pivot table including “Vendor” for the rows and “Designation” for the columns;

– in options, de-select Autofit column widths on update;

– re-name the headers in order to obtain a consistent table;

– re-size the columns so that the products are of equal width;

– put all cells in currency format (Category: Accounting, Symbol: $, Decimal places: 2).

	Designation						
VENDOR	Product A	Product B	Product C	Product D	Product E	Product F	Grand Total
Degeorges R.							
Dupont V.							
Durant V.							
Fabre D.							
Felin G.							
Marchand M.							
Martin C.							
Pizarelli B.							
Richard T.							
Grand Total							

Figure 2.3. *The departure chart*

In order to display the necessary margins, we will need to insert a calculated field in our pivot table:

– select a pivot table cell, at the intersection of a vendor and a product;

– open the ANALYZE window, then choose the icon FIELDS ELEMENTS AND SETS in the ribbon;

– select CALCULATED FIELD to open the INSERT A CALCULATED FIELD dialog box;

– in the NAME field, enter "Net margin";

– in the FORMULA field, delete the value 0 and keep the = symbol;

– in the list of fields, double click on the field "Net total", and it should appear alongside the = symbol;

– enter "*0.32" (in order to calculate the 32% margin) (Figure 2.4).

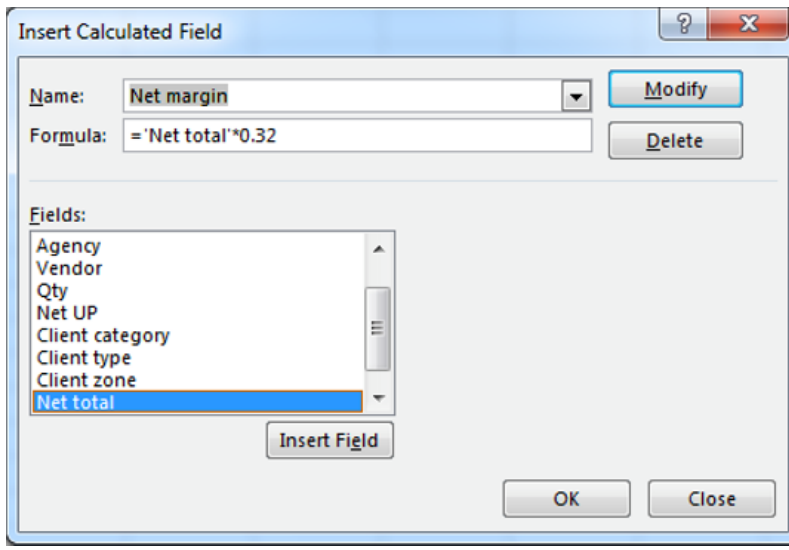


Figure 2.4. *Inserting a calculated field: Net total x 0.32*

– click on the ADD button, then OK;

– change the name "Net margin totals" (upper left of the table) to "Net margins";

– your table should be filled with this new calculation.

Net margins	Designation						
VENDOR	Product A	Product B	Product C	Product D	Product E	Product F	Grand Total
Degeorges R.	$ -	$1,126.40	$ 512.00	$ 307.20	$ 307.20	$ 460.80	$ 2,713.60
Dupont V.	$ 204.80	$ 614.40	$ 460.80	$ 716.80	$ 256.00	$ 307.20	$ 2,560.00
Durant V.	$ 768.00	$ 204.80	$1,433.60	$ 51.20	$ 102.40	$ 512.00	$ 3,072.00
Fabre D.	$ 358.40	$ 256.00	$ -	$ 204.80	$1,075.20	$ 358.40	$ 2,252.80
Felin G.	$ 512.00	$ 460.80	$ -	$ 256.00	$ 768.00	$ -	$ 1,996.80
Marchand M.	$ 716.80	$ -	$ 204.80	$1,126.40	$ 409.60	$ 716.80	$ 3,174.40
Martin C.	$ 614.40	$1,024.00	$1,280.00	$1,075.20	$ 870.40	$ 460.80	$ 5,324.80
Pizarelli B.	$ 1,024.00	$ 102.40	$ 256.00	$1,433.60	$1,280.00	$ 716.80	$ 4,812.80
Richard T.	$ 153.60	$ 204.80	$ 409.60	$ 614.40	$ 512.00	$1,024.00	$ 2,918.40
Grand Total	**$ 4,352.00**	**$3,993.60**	**$4,556.80**	**$5,785.60**	**$5,580.80**	**$4,556.80**	**$28,825.60**

Figure 2.5. *The pivot table with the margin calculation*

All that is left to do is integrate a histogram representing the value of each of the margins and that of their totals:

– select the margins contained in the “Product A” column;

– open the HOME tab;

– select the CONDITIONAL FORMATTING icon, then the DATA BARS option;

– select a font and a color. The column will be filled with bars of a length proportional to the respective values;

– repeat this step for each of the other products and the “Grand Total”;

– open the HOME tab;

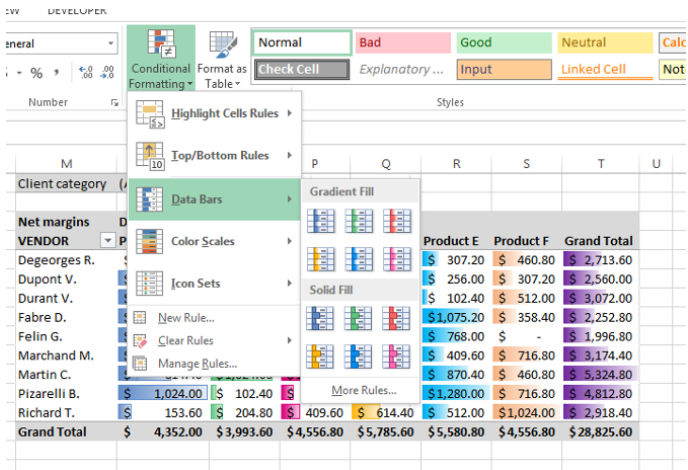


Figure 2.6. *The conditional formatting tool including its options*

– select the FORMAT AS TABLE icon;

– choose formatting.

COMMENT 2.1.– During operations with pivot tables, the column width automatically adapts to the content and this can be a nuisance. To disable this option, simply select the ANALYZE tab, click on the OPTIONS icon in the PIVOTTABLE OPTIONS section of the ribbon, then de-select AUTOFIT…UPDATE in the LAYOUT AND FORMAT tab.

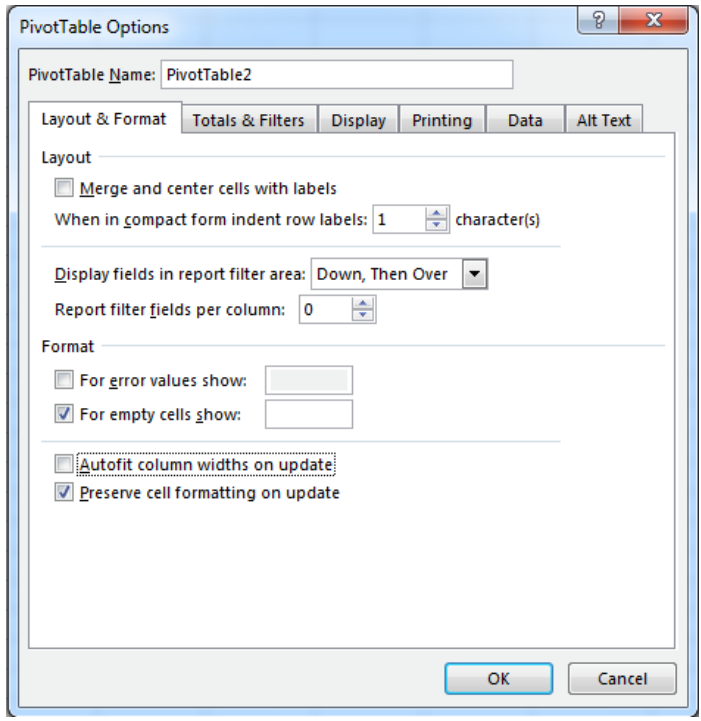
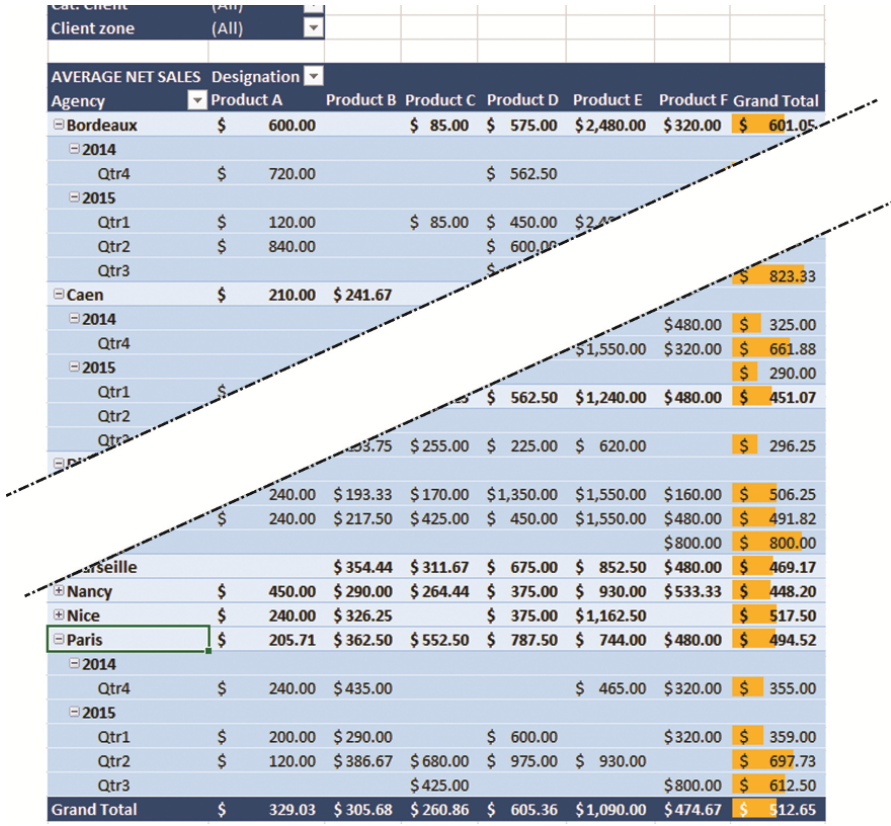


Figure 2.7. *Size configuration in the pivot table options*

2.2.2. *Calendar sections, rankings and averages*

In this second example, we would like to use a table grouping together agencies and products to show the net averages for quarterly sales for each establishment depending on the client category and the area of residence. A graph should highlight the best results: the agencies will be listed in alphabetical order while the quarters will be divided by year in ascending order.

Figure 2.8 shows the expected results.



Client zone	(All)						
AVERAGE NET SALES	Designation						
Agency	Product A	Product B	Product C	Product D	Product E	Product F	Grand Total
Bordeaux	$ 600.00		$ 85.00	$ 575.00	$2,480.00	$320.00	$ 601.05
2014							
Qtr4	$ 720.00			$ 562.50			
2015							
Qtr1	$ 120.00		$ 85.00	$ 450.00	$2,4		
Qtr2	$ 840.00			$ 600.00			
Qtr3				$			$ 823.33
Caen	$ 210.00	$ 241.67					
2014						$480.00	$ 325.00
Qtr4					$1,550.00	$320.00	$ 661.88
2015							$ 290.00
Qtr1	$			$ 562.50	$1,240.00	$480.00	$ 451.07
Qtr2							
Qtr3		3.75	$ 255.00	$ 225.00	$ 620.00		$ 296.25
	240.00	$ 193.33	$ 170.00	$1,350.00	$1,550.00	$160.00	$ 506.25
	$ 240.00	$ 217.50	$ 425.00	$ 450.00	$1,550.00	$480.00	$ 491.82
						$800.00	$ 800.00
rseille		$ 354.44	$ 311.67	$ 675.00	$ 852.50	$480.00	$ 469.17
Nancy	$ 450.00	$ 290.00	$ 264.44	$ 375.00	$ 930.00	$533.33	$ 448.20
Nice	$ 240.00	$ 326.25		$ 375.00	$1,162.50		$ 517.50
Paris	$ 205.71	$ 362.50	$ 552.50	$ 787.50	$ 744.00	$480.00	$ 494.52
2014							
Qtr4	$ 240.00	$ 435.00			$ 465.00	$320.00	$ 355.00
2015							
Qtr1	$ 200.00	$ 290.00		$ 600.00		$320.00	$ 359.00
Qtr2	$ 120.00	$ 386.67	$ 680.00	$ 975.00	$ 930.00		$ 697.73
Qtr3			$ 425.00			$800.00	$ 612.50
Grand Total	$ 329.03	$ 305.68	$ 260.86	$ 605.36	$1,090.00	$474.67	$ 512.65

Figure 2.8. *The pivot table to be obtained*

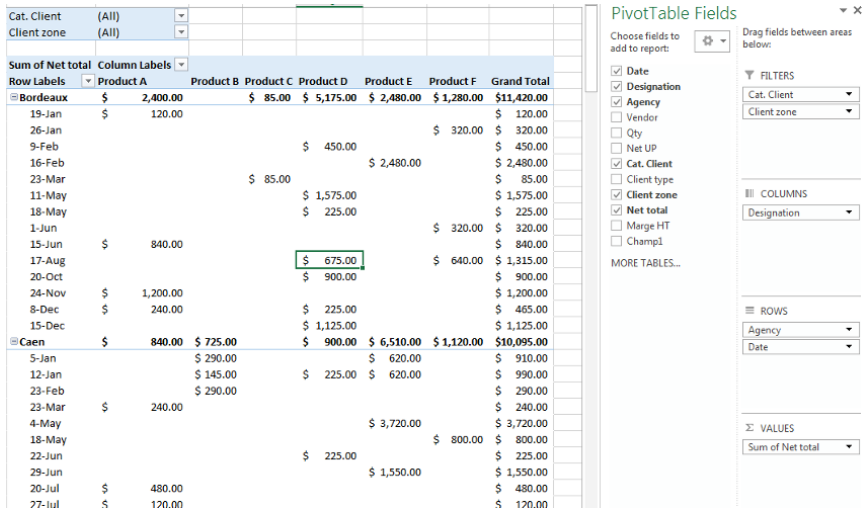
As before, we will start by creating the base table, which will include the following elements:

– FILTERS: “Cat. client” and “Client zone”;

– COLUMNS: “Designation”;

– ROWS: “Agency” and “Date”;

– Σ VALUES: “Net total amount”.



Cat. Client	(All)
Client zone	(All)

Sum of Net total	Column Labels						
Row Labels	Product A	Product B	Product C	Product D	Product E	Product F	Grand Total
Bordeaux	$ 2,400.00		$ 85.00	$ 5,175.00	$ 2,480.00	$ 1,280.00	$11,420.00
19-Jan	$ 120.00						$ 120.00
26-Jan						$ 320.00	$ 320.00
9-Feb				$ 450.00			$ 450.00
16-Feb					$ 2,480.00		$ 2,480.00
23-Mar			$ 85.00				$ 85.00
11-May				$ 1,575.00			$ 1,575.00
18-May				$ 225.00			$ 225.00
1-Jun						$ 320.00	$ 320.00
15-Jun	$ 840.00						$ 840.00
17-Aug				$ 675.00		$ 640.00	$ 1,315.00
20-Oct				$ 900.00			$ 900.00
24-Nov	$ 1,200.00						$ 1,200.00
8-Dec	$ 240.00			$ 225.00			$ 465.00
15-Dec				$ 1,125.00			$ 1,125.00
Caen	$ 840.00	$ 725.00		$ 900.00	$ 6,510.00	$ 1,120.00	$10,095.00
5-Jan		$ 290.00			$ 620.00		$ 910.00
12-Jan		$ 145.00		$ 225.00	$ 620.00		$ 990.00
23-Feb		$ 290.00					$ 290.00
23-Mar	$ 240.00						$ 240.00
4-May					$ 3,720.00		$ 3,720.00
18-May						$ 800.00	$ 800.00
22-Jun				$ 225.00			$ 225.00
29-Jun					$ 1,550.00		$ 1,550.00
20-Jul	$ 480.00						$ 480.00
27-Jul	$ 120.00						$ 120.00

Figure 2.9. *The initial table for the second example*

We will now make the necessary modifications in order to carry out the task:

– move the cursor over one of the totals, then right-click to select VALUE FIELD SETTINGS;

– a dialog box will open. In the CUSTOM NAME field enter "Average net sales";

– in the drop-down list, select AVERAGE;

– click on the NUMBER FORMAT button. A dialog box will open – select ACCOUNTING in the CATEGORY list, then click on the OK button;

– click again on the OK button to confirm your selections and to close the window. All values in the table should be re-calculated;

– at the top left of the table, replace "Average of Net total" with "AVERAGE NET SALES";

– select one of the "day" dates, right-click and select GROUP. In the drop-down list, select QUARTERS and YEARS, then click on the OK button;

– select all of the cells under "Grand total" except the one on the last line;

– open HOME tab, click on the CONDITIONAL FORMATTING icon in the STYLE section, select DATA BARS and choose a model;

– for greater clarity, you can also adjust formatting by clicking on the FORMAT AS TABLE icon in the STYLE section of the ribbon and choose a model here.

2.2.3. *Conditional calculated fields*

The aim is to calculate the total bonus for each of our vendors depending on the quarter and the month for a given year. The total bonus is a percentage based on the monthly net total of sales made in a month. It follows this rule:

– net total greater than or equal to $1,600.00: Bonus = 1.6%;

– net total greater than or equal to $2,500.00: Bonus = 2.2%

The final table should look like the one in Figure 2.10.

Vendor	Total net sales	Net premium
Degeorges R.		
2014		
Oct	$ 480.00	$ -
Dec	$ 1,600.00	$ 25.60
2015		
Jan	$ 1,440.00	$ -
Feb	$ 1,120.00	$ -
May	$ 960.00	$ -
Jun	$ 1,120.00	$
Jul	$ 1,440.00	
Aug	$	
Dupont V.		
		.60
	$	-
	,760.00	$ 28.16
	$ 1,600.00	$ 25.60
ug	$ 1,920.00	$ 30.72
Richard T.		
2014		
Nov	$ 1,600.00	$ 25.60
Dec	$ 160.00	$ -
2015		
Jan	$ 2,240.00	$ 35.84
Mar	$ 640.00	$ -
May	$ 1,120.00	$ -
Jun	$ 2,720.00	$ 59.84
Aug	$ 640.00	$ -

Figure 2.10. *The pivot table showing the total monthly bonus*

To begin with, we will create a table containing all of the necessary elements available:

– create a pivot table with “Vendor” and “Date” in ROWS;

– enter “Net total” in Σ VALUES;

– right-click on one of the dates in the table and select GROUP;

– select “Month” and “Years” from the drop-down list and click on OK. For each vendor, the column should contain a list of months for each year;

– re-name the column “Net total amount” to “Total net sales”, then change this to currency format;

Vendor	Total net sales	
Degeorges R.	**$**	**8,480.00**
2014		
Oct	$	480.00
Dec	$	1,600.00
2015		
Jan	$	1,440.00
Feb	$	1,120.00
May	$	960.00
Jun	$	1,120.00
Jul	$	1,440.00
Aug	$	320.00
Dupont V.	**$**	**8,000.00**
2014		
Oct	$	960.00
Nov	$	320.00
Dec	$	160.00
2015		
Jan	$	1,440.00
Mar	$	640.00
May	$	2,880.00

Figure 2.11. *The pivot table to be used as a base*

– create a calculated field (starting with a pivot table cell, ANALYZE tab, icon FIELDS, ITEMS AND SETS) called “Bonus” and apply the following conditional formula:

```
=IF('Net  Total'>=2500,2.2%*'Net  Total',IF('Net
Total'>=1600,1.6%*'Net Total',0))
```

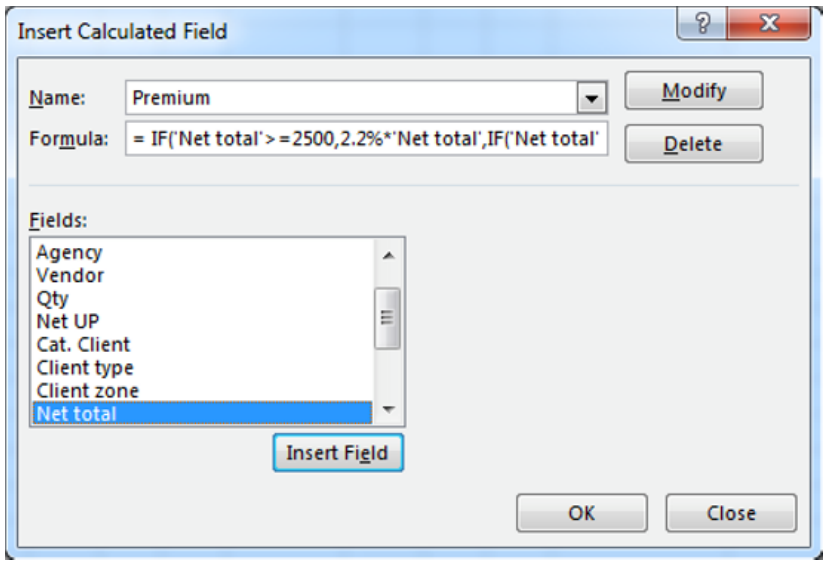


Figure 2.12. *Creating a conditional calculated field*

– switch to the field “Bonus” under Σ VALUES;

– rename the column “Net bonus”;

– note that the sub-totals for each vendor are incorrect – the pivot table tool is not capable of making the calculation, and we will therefore delete them;

– switch to one of the cells of the pivot table, open the DESIGN tab, click on the SUB-TOTALS icon in the ribbon and tick DO NOT SHOW SUB-TOTALS;

– follow the same instructions for the grand totals at the bottom of the table. In the ANALYZE tab, click on the OPTIONS icon under PIVOT TABLE OPTIONS in the ribbon. A dialog box will open – in the TOTALS AND FILTERS tab, untick SHOW GRAND TOTALS FOR COLUMNS;

– click on the OK button to confirm.

2.2.4. *Slicers, filtering and calculated fields*

We have just seen a few examples of the use of calculated fields. We will now link this to the filter, the calculated field and the slicer.

In the database that I use, each of the vendors made a turnover of between $4,725.00 and $11,520.00 for products A to F.

I want my pivot table to show me the target figure that the six least effective vendors should meet for 2016, knowing that it should be 12% higher than 2015.

To begin with, we will use the very simple pivot table from Figure 2.13.

Net total	Years		
Vendor	2014	2015	Grand Total
Degeorges R.	$ 1,855.00	$ 6,835.00	$ 8,690.00
Dupont V.	$ 1,065.00	$ 7,580.00	$ 8,645.00
Durant V.	$ 1,905.00	$ 5,300.00	$ 7,205.00
Fabre D.	$ 770.00	$ 9,325.00	$ 10,095.00
Felin G.	$ 3,555.00	$ 4,725.00	$ 8,280.00
Marchand M.	$ 6,140.00	$ 11,520.00	$ 17,660.00
Martin C.	$ 2,840.00	$ 9,110.00	$ 11,950.00
Pernot C.		$ 8,095.00	$ 8,095.00
Picard D.	$ 2,205.00	$ 5,780.00	$ 7,985.00
Pizarelli B.	$ 3,690.00	$ 7,730.00	$ 11,420.00
Richard T.	$ 2,470.00	$ 8,150.00	$ 10,620.00
Grand Total	**$ 26,495.00**	**$ 84,150.00**	**$ 110,645.00**

Figure 2.13. *The initial pivot table, before modification*

The following operations will delete the column from 2014, display the six least effective vendors from 2015 and add a column that will calculate their targets for 2016:

– select one of the cells in the pivot table;

– in the ANALYZE tab, click on the INSERT SLICER icon in the ribbon;

– a dialog box will open – tick “Date”, then click on the OK button (Figure 2.14);

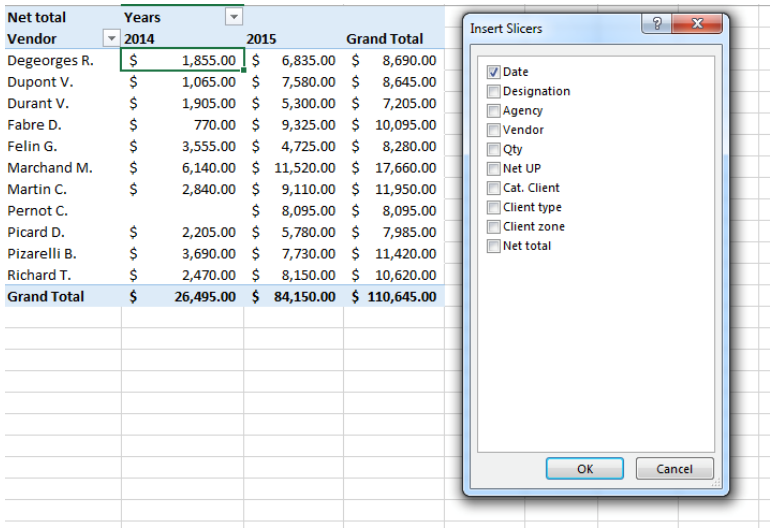


Figure 2.14. *Selecting the field for the slicer*

– a filter interface will open – double-click on 2015 (Figure 2.15).

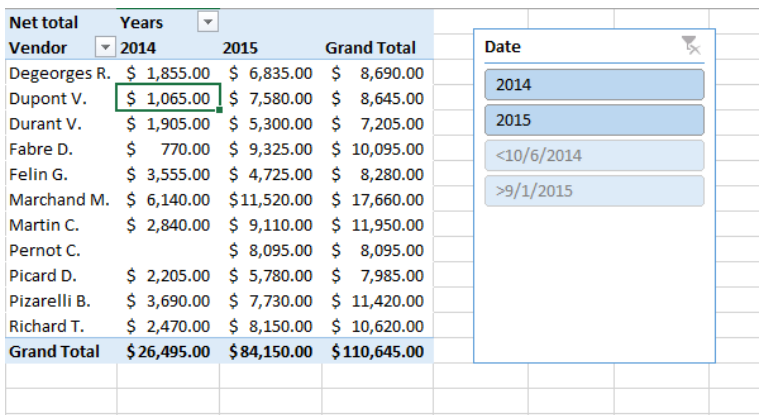


Figure 2.15. *The pivot table and the filter interface for selecting a slicer*

COMMENT 2.2.– The filter interface for slicing is still available and you can modify your options at any time by clicking on one of the relevant filtering buttons.

If you do not want to use the filter, which you should keep, it is possible to delete 2014 from the pivot table by using the slicer management option.

This involves taking the following steps (replacing the steps from before):

– select the 2014 cell in the pivot table;

– right-click and select FILTER, then DATE FILTERS (Figure 2.16);

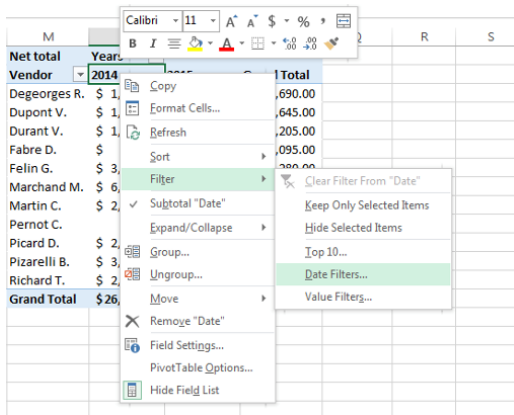


Figure 2.16. *Selecting the date filters*

– a dialog box will open – select IS AFTER in the drop-down menu, then enter 01/01/2015 in the adjacent field;

– click on the OK button. Your pivot table will now only contain data from 2015 (Figure 2.17).

M	N	O
Net total	**Years**	
Vendor	**2015**	**Grand Total**
Degeorges R.	$ 6,835.00	$ 6,835.00
Dupont V.	$ 7,580.00	$ 7,580.00
Durant V.	$ 5,300.00	$ 5,300.00
Fabre D.	$ 9,325.00	$ 9,325.00
Felin G.	$ 4,725.00	$ 4,725.00
Marchand M.	$11,520.00	$11,520.00
Martin C.	$ 9,110.00	$ 9,110.00
Pernot C.	$ 8,095.00	$ 8,095.00
Picard D.	$ 5,780.00	$ 5,780.00
Pizarelli B.	$ 7,730.00	$ 7,730.00
Richard T.	$ 8,150.00	$ 8,150.00
Grand Total	**$84,150.00**	**$84,150.00**

Figure 2.17. *The pivot table showing only 2015 data*

We will now remove all but the six least effective vendors and create our calculated item, the target figure for 2016:

– select one of the vendors;

– right-click and select FILTER, then TOP 10;

– a dialog box will open – configure, using the different drop-down menus: BOTTOM; 6; ITEMS; BY "Net Total" (Figure 2.18);

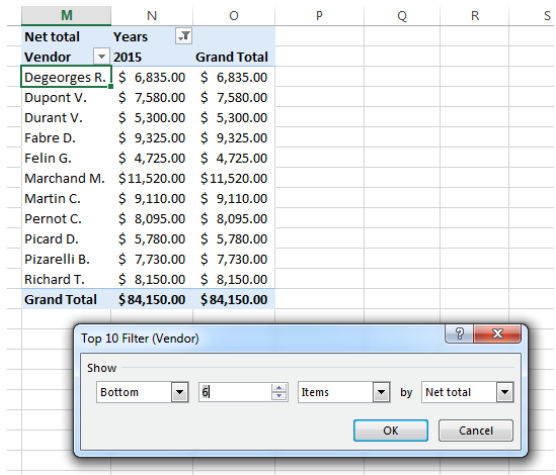


Figure 2.18. *The filter for selecting the six least effective vendors*

– your pivot table should now only contain the six least effective vendors (Figure 2.19);

M	N	O
Net total	**Years**	
Vendor	**2015**	**Grand Total**
Degeorges R.	$ 6,835.00	$ 6,835.00
Dupont V.	$ 7,580.00	$ 7,580.00
Durant V.	$ 5,300.00	$ 5,300.00
Felin G.	$ 4,725.00	$ 4,725.00
Picard D.	$ 5,780.00	$ 5,780.00
Pizarelli B.	$ 7,730.00	$ 7,730.00
Grand Total	**$ 37,950.00**	**$ 37,950.00**

Figure 2.19. *The pivot table showing the six least effective vendors*

– in the ANALYZE tab, click on the FIELDS, ITEMS AND SETS icon in the ribbon and select CALCULATED FIELD;

– in the NAME field, enter "2016 Target";

– in the FORMULA field, delete the value 0, then double-click on "Net Total" in the drop-down menu and enter "*1.12" to calculate the 12% increase required in order to meet the target (Figure 2.20);

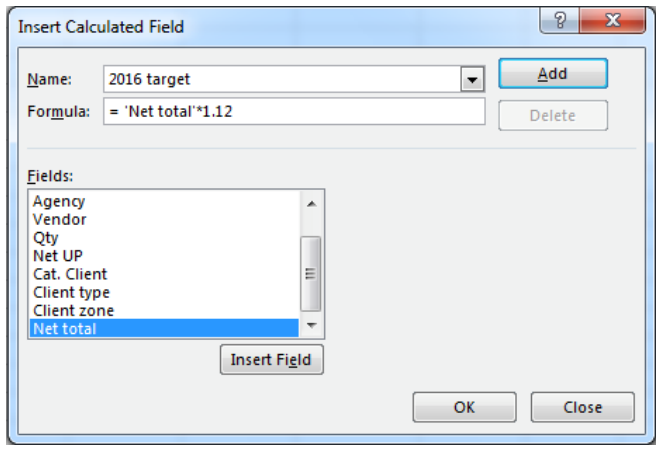


Figure 2.20. *Configuring the calculated field for the 2016 target*

– two new columns will appear in your pivot table, "Sum of 2016 target" and "Total Sum of 2016 Target" (Figure 2.21);

M	N	O	P	Q
	Years			
	2015		Total Net total	Total Sum of 2016 target
Vendor	Net total	Sum of 2016 target		
Degeorges R.	$ 6,835.00	$ 7,655.20	$ 6,835.00	$ 7,655.20
Dupont V.	$ 7,580.00	$ 8,489.60	$ 7,580.00	$ 8,489.60
Durant V.	$ 5,300.00	$ 5,936.00	$ 5,300.00	$ 5,936.00
Felin G.	$ 4,725.00	$ 5,292.00	$ 4,725.00	$ 5,292.00
Picard D.	$ 5,780.00	$ 6,473.60	$ 5,780.00	$ 6,473.60
Pizarelli B.	$ 7,730.00	$ 8,657.60	$ 7,730.00	$ 8,657.60
Grand Total	**$ 37,950.00**	**$ 42,504.00**	**$ 37,950.00**	**$ 42,504.00**

Figure 2.21. *The two columns created by adding the "2016 Target" field*

– rename the first “Target for 2016”;

– select the ANALYZE tab, click on the OPTIONS icon under PIVOT TABLE OPTIONS in the ribbon, then in the dialog box, under TOTALS AND FILTERS, untick SHOW GRAND TOTALS FOR ROWS;

– click on the OK button to confirm.

The table that you should obtain should be similar to the one in Figure 2.22.

	Years	
	2015	
Vendor	Net total	Target for 2016
Degeorges R.	$ 6,835.00	$ 7,655.20
Dupont V.	$ 7,580.00	$ 8,489.60
Durant V.	$ 5,300.00	$ 5,936.00
Felin G.	$ 4,725.00	$ 5,292.00
Picard D.	$ 5,780.00	$ 6,473.60
Pizarelli B.	$ 7,730.00	$ 8,657.60
Grand Total	**$ 37,950.00**	**$ 42,504.00**

Figure 2.22. *The pivot table with the column “Net Total” for 2015 and the targets for vendors for 2016*

2.2.5. *Calculated items*

We have previously seen a number of examples of the use of calculated fields, but there is another possibility that limits the range of the target, and this involves calculated items. In this instance, the calculation only applies to some of the items available in one of the ribbons on the database, not all of them.

Looking at a recap pivot table for 2015 that compares products with agencies, we notice that “Nice”, “Bordeaux” and “Caen” made fewer sales than the other agencies, all products combined (Figure 2.23).

Qty 2015	Agency									
Designation	Bordeaux	Caen	Dijon	Lille	Lyon	Marseille	Nancy	Nice	Paris	Grand Total
Product A	8	7	14	2	4		15	2	6	58
Product B		5		4	7	12	4	8	14	54
Product C	1		2	8	7	21	15		13	67
Product D	13	2	22	12	14	6	1	1	21	92
Product E	8	21	8	5	10	11	12	10	9	94
Product F	8	5	14	15	12	7	5		7	73
Grand Total	**38**	**40**	**60**	**46**	**54**	**57**	**52**	**21**	**70**	**438**

Figure 2.23. *The quantities sold by each of the agencies in 2015*

In order to rectify this imbalance, we predict an increase in the number of sales:

– 50% more for the agency in Nice;

– 40% more for the agencies in Bordeaux and Caen.

In order for the vendors in each of these agencies to have a clearer idea of what quantities they will need to sell in 2016, we will create the pivot table in Figure 2.24, using the previous recap pivot table (Figure 2.23).

Qty 2015	Agency					
Designation	Bordeaux	Bordeaux 2016	Caen	Caen 2016	Nice	Nice 2016
Product A	8	12	7	10	2	3
Product B		0	5	7	8	12
Product C	1	2		0		0
Product D	13	19	2	3	1	2
Product E	8	12	21	30	10	15
Product F	8	12	5	7		0
Grand Total	**38**	**57**	**40**	**57**	**21**	**32**

Figure 2.24. *The pivot table to be obtained, including columns for 2016 for Bordeaux, Caen and Nice*

– In the pivot table, open the pop-up menu in the cell containing "Agency" by clicking on the filter icon and keep only the agencies in Nice, Caen and Bordeaux checked;

– click on one of the agency names to select it;

– in the ANALYZE tab, click on the FIELDS, ITEMS AND SETS icon in the ribbon and select CALCULATED ITEM;

– in the NAME field, enter "Nice 2016";

– switch to the FORMULA field, delete the 0 value, enter "CEILING" (behind the equal sign, click on "Agency" in the drop-down menu, then double-click on "Nice" in the drop-down list of items, then add "*1.5,1)" to calculate the 50% increase.

COMMENT 2.3.– CEILING is present in order to round the product up to the nearest whole number. The figure 1 behind the comma gives the rounded-up value.

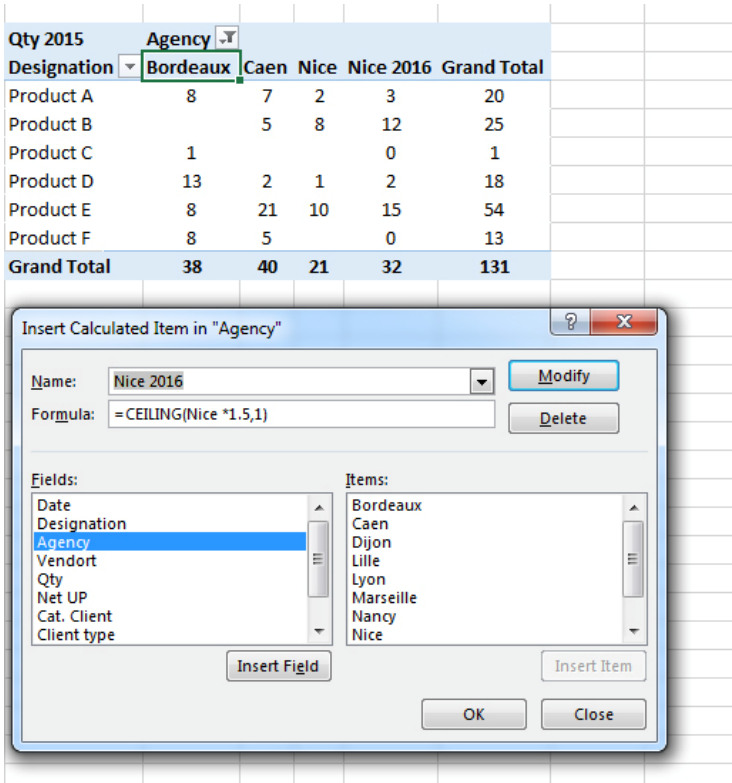


Figure 2.25. *Creating the column that will contain the calculated item "Nice 2016". Note the formula for calculating the 50% increase and the "CEILING" function*

– click on the OK button to confirm the creation of your new column;

– repeat the two previous operations with the agencies for Bordeaux and Caen, entering a coefficient of 1.4 corresponding to 40%;

– select the ANALYZE tab, click on the OPTIONS icon under PIVOT TABLE OPTIONS in the ribbon. A dialog box will open – under TOTALS AND FILTERS, untick SHOW GRAND TOTALS FOR ROWS;

– click on the OK button to confirm;

– open the pop-up menu for the cell containing "Agency" by clicking on the filter icon, then click on the option SORT A TO Z. The aim here will be to place the columns in order for each of the cities.

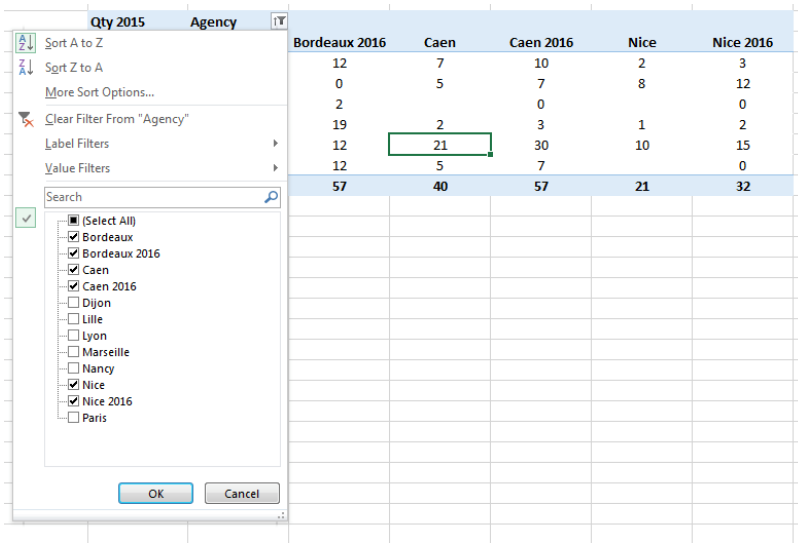


Figure 2.26. *The pop-up menu for agencies, showing options for sorting, among others*

2.3. Multiple databases

A recurring question in the use of pivot tables concerns the possibility of extracting data from several tables simultaneously.

In a Microsoft Excel spreadsheet, by definition there can only be one single database defined on a range of cells containing a header line that describes each of the fields (ribbons) in the database.

This is the type of database that we have used in the previous examples in this chapter.

There is, however, a very useful solution, which is little known despite the fact that a very powerful version has been developed in Microsoft Excel 2013. This is the table manager (for tables or data tables).

A range of cells can be transformed into a data table. I will not go into detail here on all of the possibilities that this method offers, but should you wish to know more, please consult the bibliography at the end of the volume and the Internet links.

COMMENT 2.4. –

– Some of the following examples are only possible in the 2013 version of Microsoft Excel. To use them in the 2010 version, you will need to download an add-in called "PowerPivot", available to download on the Microsoft website.

– For other versions of Excel or other spreadsheets, you should be aware that not all of the features mentioned will be available.

To give you an example of the use of pivot tables linked to tables, we will need to modify our initial database (see section 1.2).

It should be clarified that table management is in fact an extrapolation of the technique used in *Relationship Database Management Systems (RDBMS)* where tables[2] are linked to each other by *relationships* (links) with specific characteristics (*cardinalities),* as found in Microsoft Access, Oracle, IBM DB2, Sybase etc. (see the Bibliography at the end of the volume).

2.3.1. *New tables for the database*

Our database will have two tables, "Sales" and "Products". The first will be a modification of the table we have been using up to this point.

"Sales" table:

– Date: date of sale including the day, month and year – format: dd/mm/yy;

– Reference: FF NNN (family, n°) – format: whole number, 00 000;

– Agency: location of the sales agency – format: text;

– Vendor: vendor name – format: text;

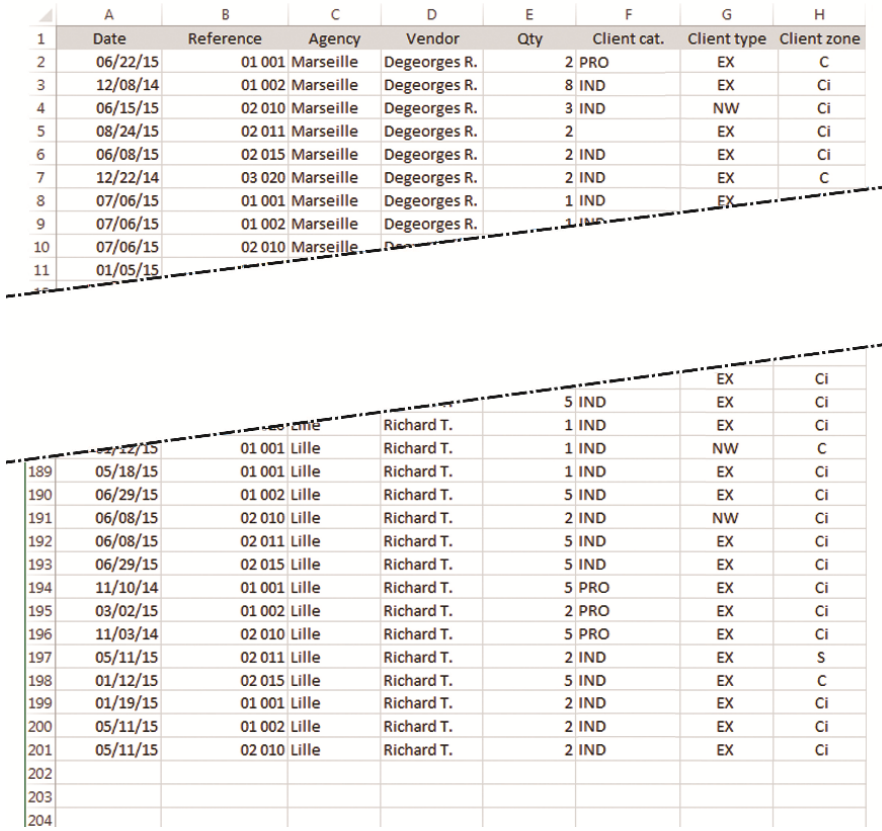
– Qty: unit quantity – format: whole number, 0;

– Client category: IND (individual), PRO (professional) – format: text;

– Client type: N (new), EX (existing) – format: text;

– Client residence zone: Ci (City), Di (District), C (County), S (State), OS (Outside State) – format: text;

2 The vocabulary "tables", "relationships", "requests" and "cardinalities" is specific to the operation and use of databases connected to what we refer to as relational algebra. In the Bibliography at the end of this volume there are studies and Internet links relating to this subject.



	A	B	C	D	E	F	G	H
1	Date	Reference	Agency	Vendor	Qty	Client cat.	Client type	Client zone
2	06/22/15	01 001	Marseille	Degeorges R.	2	PRO	EX	C
3	12/08/14	01 002	Marseille	Degeorges R.	8	IND	EX	Ci
4	06/15/15	02 010	Marseille	Degeorges R.	3	IND	NW	Ci
5	08/24/15	02 011	Marseille	Degeorges R.	2		EX	Ci
6	06/08/15	02 015	Marseille	Degeorges R.	2	IND	EX	Ci
7	12/22/14	03 020	Marseille	Degeorges R.	2	IND	EX	C
8	07/06/15	01 001	Marseille	Degeorges R.	1	IND	EX	
9	07/06/15	01 002	Marseille	Degeorges R.	1	IND		
10	07/06/15	02 010	Marseille	Degeorges R.				
11	01/05/15							
							EX	Ci
					5	IND	EX	Ci
			Lille	Richard T.	1	IND	EX	Ci
		01 001	Lille	Richard T.	1	IND	NW	C
189	05/18/15	01 001	Lille	Richard T.	1	IND	EX	Ci
190	06/29/15	01 002	Lille	Richard T.	5	IND	EX	Ci
191	06/08/15	02 010	Lille	Richard T.	2	IND	NW	Ci
192	06/08/15	02 011	Lille	Richard T.	5	IND	EX	Ci
193	06/29/15	02 015	Lille	Richard T.	5	IND	EX	Ci
194	11/10/14	01 001	Lille	Richard T.	5	PRO	EX	Ci
195	03/02/15	01 002	Lille	Richard T.	2	PRO	EX	Ci
196	11/03/14	02 010	Lille	Richard T.	5	PRO	EX	Ci
197	05/11/15	02 011	Lille	Richard T.	2	IND	EX	S
198	01/12/15	02 015	Lille	Richard T.	5	IND	EX	C
199	01/19/15	01 001	Lille	Richard T.	2	IND	EX	Ci
200	05/11/15	01 002	Lille	Richard T.	2	IND	EX	Ci
201	05/11/15	02 010	Lille	Richard T.	2	IND	EX	Ci
202								
203								
204								

Figure 2.27. *An example of the range of cells for the "Sales" table*

"Products" table:

– Reference: FF NNN (family, n°) – format: whole number, 00 000;

– Designation: product label, "Product A" to "Product F" – format: text;

– Net UP: unit price before tax – format: _($* #,##0.00_);

– Packaging: number of products per unit of sales – format: whole number, 0;

– Availability: number of days prior to delivery (IM: immediate, nD: x days, nW: x weeks) – format: text;

J	K	L	M	N
Reference	Designation	Net UP	Packaging	Availability
01 001	Product A	$ 120.00	1	7D
01 002	Product B	$ 145.00	1	IM
02 010	Product C	$ 85.00	4	10D
02 011	Product D	$ 225.00	2	IM
02 015	Product E	$ 310.00	4	3D
03 020	Product F	$ 160.00	1	2W

Figure 2.28. *An example of the range of cells for the "Products" table*

2.3.2. *Creating data tables*

We will now transform our two cell ranges into data tables:

– switch to one of the cells of the "Sales" cell range;

– select the INSERT tab;

– under TABLES on the ribbon, click on the TABLE icon;

– a dialog box, CREATE TABLE, will open. Confirm that the range indicated covers the entire cell range and click on the OK button (Figure 2.29);

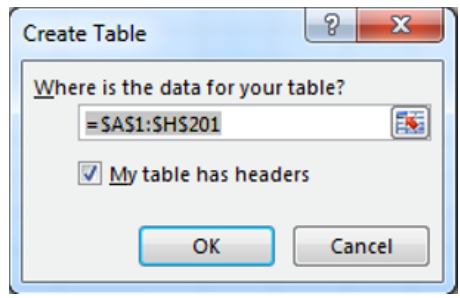


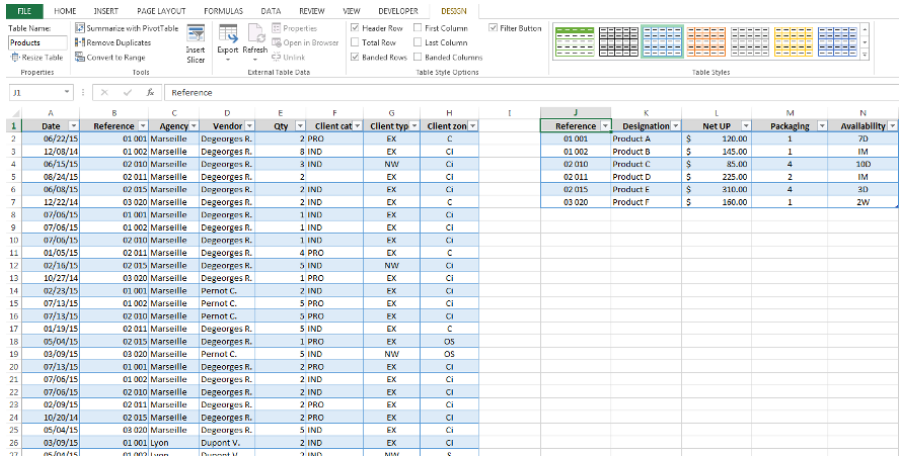
Figure 2.29. *Creating a table*

– repeat the same actions for the second cell range ("Products");

– select the DESIGN tab;

– under PROPERTIES, enter the table name: "Products" instead of the name created by default;

– after having selected a cell from the "Sales" table, repeat the same actions and re-name it.



Date	Reference	Agency	Vendor	Qty	Client cat	Client typ	Client zon
06/22/15	01 001	Marseille	Degeorges R.	2	PRO	EX	C
12/08/14	01 002	Marseille	Degeorges R.	8	IND	EX	CI
06/15/15	02 010	Marseille	Degeorges R.	3	IND	NW	CI
08/24/15	02 011	Marseille	Degeorges R.	2		EX	CI
06/08/15	02 015	Marseille	Degeorges R.	2	IND	EX	CI
12/22/14	03 020	Marseille	Degeorges R.	2	IND	EX	C
07/06/15	01 001	Marseille	Degeorges R.	1	IND	EX	CI
07/06/15	01 002	Marseille	Degeorges R.	1	IND	EX	CI
07/06/15	02 010	Marseille	Degeorges R.	1	IND	EX	CI
01/05/15	02 011	Marseille	Degeorges R.	4	PRO	EX	C
02/16/15	02 015	Marseille	Degeorges R.	5	IND	NW	CI
10/27/14	03 020	Marseille	Degeorges R.	1	PRO	EX	CI
02/23/15	01 001	Marseille	Pernot C.	2	IND	EX	CI
07/13/15	01 002	Marseille	Pernot C.	5	PRO	EX	CI
07/13/15	02 010	Marseille	Pernot C.	5	PRO	EX	CI
01/13/15	02 011	Marseille	Degeorges R.	5	IND	EX	C
05/04/15	02 015	Marseille	Degeorges R.	1	PRO	EX	OS
03/09/15	03 020	Marseille	Pernot C.	5	IND	NW	OS
07/13/15	01 001	Marseille	Degeorges R.	2	PRO	EX	CI
07/06/15	01 002	Marseille	Degeorges R.	2	IND	EX	CI
07/06/15	02 010	Marseille	Degeorges R.	2	IND	EX	CI
02/09/15	02 011	Marseille	Degeorges R.	2	PRO	EX	CI
10/20/14	02 015	Marseille	Degeorges R.	2	PRO	EX	CI
05/04/15	03 020	Marseille	Degeorges R.	5	IND	EX	CI
03/09/15	01 001	Lyon	Dupont V.	2	IND	EX	CI

Reference	Designation	Net UP	Packaging	Availability
01 001	Product A	$ 120.00	1	7D
01 002	Product B	$ 145.00	1	IM
02 010	Product C	$ 85.00	4	10D
02 011	Product D	$ 225.00	2	IM
02 015	Product E	$ 310.00	4	3D
03 020	Product F	$ 160.00	1	2W

Figure 2.30. *The two tables: "Sales" (on the left) and "Products" (on the right)*

2.3.3. *Relationships between tables*

Now that the tables have been created, we must now link them (using relationship or link) through a shared column, referred to here as "Reference".

Effectively, in the "Sales" table, entering a product reference makes it possible to find out information relating to that product, whether this is its unit price before tax, its packaging or its availability:

– move the cursor to one of the tables;

– select the DATA tab;

– under DATA TOOLS, click on the RELATIONSHIPS icon;

– a dialog box will open – click on the NEW button;

– a new dialog box, CREATE RELATIONSHIP, will appear;

– in the drop-down menu, TABLE, select "Sales";

– in the drop-down menu, RELATED TABLE, select "Products";

– in the drop-down menu COLUMN (FOREIGN), select "Reference";

– in the drop-down menu RELATED COLUMN (PRIMARY), select "Reference";

COMMENT 2.5.– The two tables can have columns (fields) with different names, but they can still be linked provided that they are the same type. The same principle applies to relational databases.

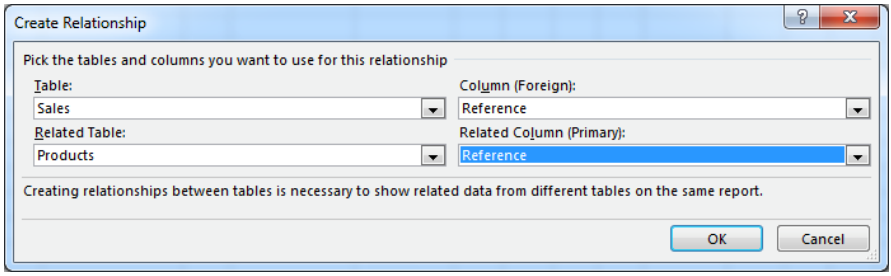


Figure 2.31. *The dialog box for creating a relationship*

– click on the OK button;

– the dialog box will close and your new relationship will appear in the MANAGE RELATIONSHIPS) box (Figure 2.32);

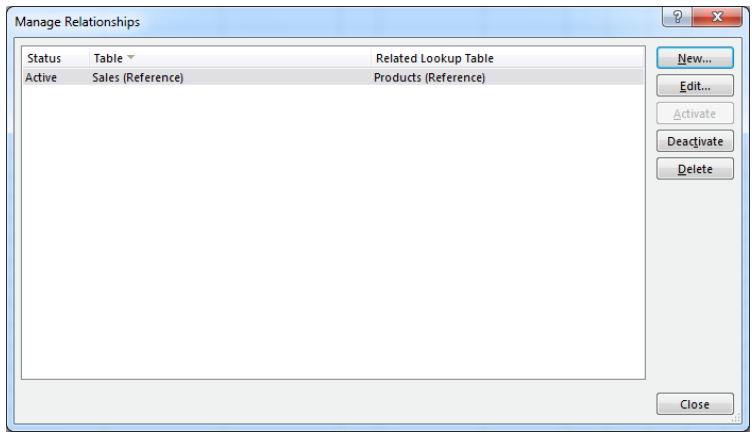


Figure 2.32. *The new relationship*

– click on the CLOSE button.

2.3.4. *Using multiple tables to create a pivot table*

Now that we have these two linked tables, we would like to show the pivot table from Figure 2.33.

Qty sold	Agency								
	Bordeaux	Caen	Dijon	Lille	Lyon		Nice	Paris	Grand Total
Designation	Pizarelli B.	Fabre D.	Marchand M	Richard T.	Dupont V.	Picard D.	Felin G.	Martin C.	
Product A	16	10	20	12		11	2	25	111
Product B	5	4	13	10		3	1	11	19	93
Product C	6	6	11	9		6	3	5	8	74
Product D	23	10	7			10	10	6	13	112
Product E	7	7	9			19		13	13	110
Product F	3	7	2		5	11		2	9	63
Grand Total	60	44	62		17	60	14	39	87	563

Figure 2.33. *The pivot table to be created*

We can see that the quantities, the vendors and the agencies come from the "Sales" table, while the designation of products comes from the "Products" table.

The previously created relationship establishes a link between the two tables using the "Reference" column.

In order to produce a dashboard summarizing sales, carry out the following instructions:

– move your cursor to the "Sales" table;

– select the INSERT tab;

– under TABLES, click on the PIVOT TABLE icon;

– a dialog box will open – confirm that you have "Sales" in the TABLE/RANGE field;

– under LOCATION, enter the cell defining the location destination for your pivot table;

– tick ADD THIS DATA TO THE DATA MODEL in order to take into account the two tables as well as their relationship (Figure 2.34);

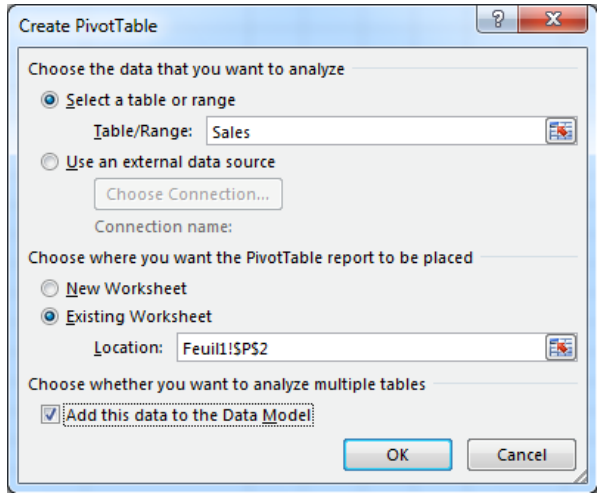


Figure 2.34. *Creating the pivot table using multiple tables*

– click on the OK button to confirm.

The fields area of the pivot table should look like the one in Figure 2.35. In the ACTIVE tab, you should be able to see your two tables;

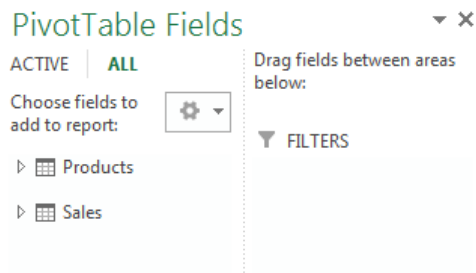


Figure 2.35. *The fields area of the pivot table showing the two active tables: "Products" and "Sales"*

– put the "Agency" and "Vendor" fields in the COLUMNS area;

– put the "Designation" field in the ROWS area;

– put the "Qty" field in the Σ VALUES area;

– rename the different items: table, row, header column and format the pivot table (Figure 2.36);

Qty sold	Agency		
	Bordeaux	Bordeaux Total	Ca
Designation	Pizarelli B.		Fabı
Product A	16	16	
Product B	5	5	
Product C	6	6	
Product D	23	23	
Product E	7	7	
Product F	3	3	
Grand Total	60	60	

Figure 2.36. *The renamed headers: "Qty sold", "Designation" and "Agency"*

– move your cursor over the pivot table, select the DESIGN tab;

– under LAYOUT, click on the SUBTOTALS icon and select DO NOT SHOW SUB TOTALS in order to make them disappear for each of the agencies.

2.4. Limits and constraints with calculated fields

We will re-use our first database, only now we will imagine that we want to delete the Net Total column, regarding it as unnecessary since it can be replaced by a calculated field in a pivot table.

The Net Total column is the result of a row by row calculation multiplying the product Quantity x Unit price before tax.

The final table should look like the one in Figure 2.37.

Designation	Total qty	Net unit price	Net total
Product A	85	$ 120.00	$ 10,200.00
Product B	78	$ 145.00	$ 11,310.00
Product C	89	$ 85.00	$ 7,565.00
Product D	113	$ 225.00	$ 25,425.00
Product E	109	$ 310.00	$ 33,790.00
Product F	89	$ 160.00	$ 14,240.00
Grand Total	**563**	**$ 177.05**	**$ 102,530.00**

Figure 2.37. *The table to be obtained*

In the following section, I will show you a solution for tackling this issue while avoiding the pitfalls involved with a pivot table calculator.

At first glance, the solution to the problem seems rather straightforward.

Take the following steps:

– move the “Designation” of products into the ROWS section;

– move the “Quantity” and the “Unit price before tax” into the Σ VALUES section;

– create a calculated field called “Net Total”, corresponding to the “Quantity” multiplied by the “Unit price before tax”;

– move the latter into the Σ VALUES section;

– in the table, replace the headers for the columns with “Designation”, “Total qty”, “Net unit price” and “Net Total” ;

– select all of the numerical values from the table, switch to the HOME tab, then select CURRENCY from the drop-down menu in the NUMBER section of the ribbon.

Although the steps taken appear logical, the results displayed are incorrect.

Designation	Total qty	Net unit price	Net total
Product A	85	$ 3,720.00	$ 316,200.00
Product B	78	$ 5,365.00	$ 418,470.00
Product C	89	$ 2,465.00	$ 219,385.00
Product D	113	$ 9,450.00	$ 1,067,850.00
Product E	109	$ 9,610.00	$ 1,047,490.00
Product F	89	$ 4,800.00	$ 427,200.00
Grand Total	**563**	**$ 35,410.00**	**$ 19,935,830.00**

Figure 2.38. *The resulting table from our operations. The values obtained are inconsistent*

In reality, there has been no mistake on the part of the pivot table calculator.

In the “Net unit price” column, it simply adds the “Net unit price” of the product as many times as there are lines containing this information.

In the "Net Total" column, it multiplies the "Net unit price" by the quantity. For instance, for the first row: *85 × $3,720.00 = $316,200.00*.

It then follows that the column totals are also inconsistent.

In order to resolve this issue, the total for the "Net unit price" should not be kept in the Σ VALUES section but instead it should be changed to an average. The average of a set of equal values (here this is the unit price of a product) is identical to one of these values.

In terms of the calculated field, the formula must be modified so that it can calculate using the average of the unit price before tax.

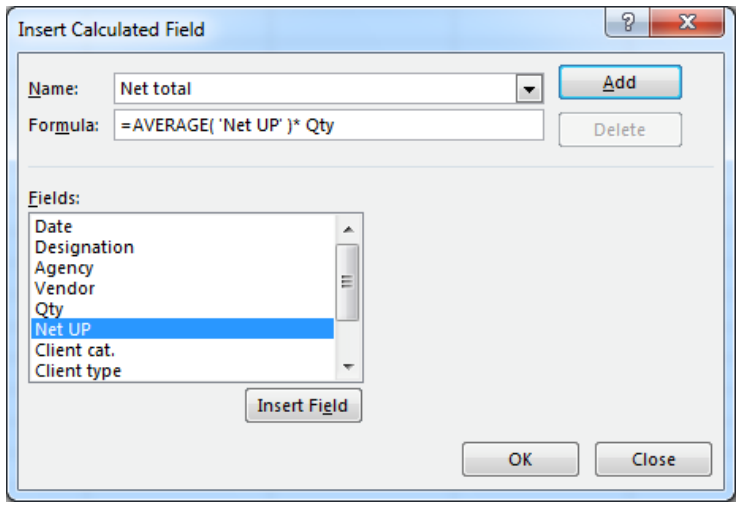


Figure 2.39. *The modified formula for calculating the "Net Total"*

This simple example shows the limits of pivot tables in certain specific cases. In principle, it is generally more useful, less risky and easier to integrate a calculation by adding a column to the corresponding table in the database. The values contained in this column can be easily used within a pivot table.

COMMENT 2.6.– The solution that I propose for this example would not work if the net unit price of a product changed over time, given that it would no longer be represented by the average for the entirety of the given period.

2.5. Conclusion

In this chapter, I have shown some of the possible ways of using this excellent tool, the pivot table calculator, in Microsoft Excel.

In doing so I have left out a number of other possibilities and functions, whether linked to pivot tables or not, most notably the potential for importing databases, analyzing scenarios, validating and consolidating data, etc.

I would invite you to investigate further by consulting the Bibliography and the Internet links provided at the end of this book.

3

Scheduling and Planning Using a Project Manager

3.1. Reminders and information

In this chapter, I will show you how to build a project using the Microsoft Project 2013 project manager. The aim will be to allow you to discover the potential of this type of program and possible interactions with other tools.

It is not my intention to teach you how to use all of the features of this manager, given that a volume like this one has not been designed for such a purpose.

The way in which this information will be presented to you will be based on the concepts explored in detail in Chapter 5, Volume 1. To this we will add resource implementation and management, awareness of the over-allocation of resources and opportunities for reducing and leveling in order to meet imposed constraints, as well as the monitoring of the project.

These studies will be based on real-life examples, taken from the industry. Through these means, I hope to be able to show you the full range of this program's capabilities for managing and monitoring one or several projects within a company. With a touch of nostalgia, I still remember how hard it was and how long it took to do the same thing some decades ago.

Everything contained in this chapter can easily be partly or fully adapted for use with other project managers, such as those mentioned in section 10.3.2 of Volume 1 of this work.

Modeling and Simulation of Logistics Flows 2: Dashboards, Traffic Planning and Management,
First Edition. Jean-Michel Réveillac.

3.2. Example: designing and building a machine-tool

3.2.1. *Scenario*

The company, MecaTools, specialists in custom-made machine tools, have been asked by one of their clients to design a hydraulic press for stamping aluminum plates. In order to carry out this order, they have been given a design brief specifying the necessary technical characteristics for the machine.

The design and the construction, as well as tests and client approval will be carried out exclusively in their workshops. For this purpose, the board has appointed a project manager who will be responsible for scheduling and planning the work to be carried out.

After having analyzed the list of specifications provided by the client, the project manager worked with a support team to draw up a precedence table showing the main tasks to be carried out.

Task	*Designation*	*Duration*	*Predecessor*
A	Defining the design specification	4wks	–
Design			
B	Functional design	3wks	A
C	Detailed design	4wks	B
D	Mechanical design	2wks	C
E	Hydraulic design	2wks	C
F	Automatic computer design	1wks	C
Prototype construction			
G	Mechanical construction	7wks	D
H	Assembling the hydraulic system	4d	E, G
I	Assembling the sensors and PLC	3d	F, G
J	Wiring (electronic, sensors, field network, etc.)	4d	H, I
K	Developing and coding PLC application	4wks	F
L	Developing and coding computer application	5wks	F
M	Linking network to information systems	1d	J, L
N	Integrating mechanics, hydraulics, automation, etc.	6d	I, J, K
Tests and checks			
O	Network test	2d	M, N
P	Testing and checking the prototype	1wks	O, Q
Q	Technical documentation	2wks	C
Marketing			
R	Finalizing technical documentation	2d	P, Q
S	Marketing material	1wks	P, Q
T	Client presentation and approval	1d	R, S

Table 3.1. *Tasks and predecessors*

The team attached to this project is as follows (the equipment and the raw materials used are not taken into account during the planning stage, with this managed separately by the MecaTools CAPM).

The hourly costs given are the average hourly costs, including tax, for an employee or a service.

Name	Service	No.	Hourly rate ($/h)	Calendar
Project manager	Management	1	$ 52.00	Schedule 1
Mechanical project assistant	Production	1	$ 38.00	Schedule 1
Hydraulic project assistant	Production	1	$ 38.00	Schedule 1
Computer automation project assistant	Production	1	$ 41.00	Schedule 1
Design office (5 people)	Production	1	$ 215.00	Schedule 2
Mechanical engineer	Production	1	$ 42.00	Schedule 3
Electrotechnical engineer	Production	1	$ 44.00	Schedule 3
Hydraulic engineer	Production	1	$ 42.00	Schedule 3
Software engineer	Production	1	$ 44.00	Schedule 3
Programmer	IT	2	$ 35.50	Schedule 2
Fitter	Production	5	$ 18.00	Schedule 3
Technician	Production	4	$ 24.50	Schedule 3
Secretary-editor	Administration	1	$ 20.00	Schedule 4
Marketing (3 people)	Administration	1	$ 160.00	Schedule 4
Commercial services (3 people)	Administration	1	$ 190.00	Schedule 4
Logistics (2 people)	Administration	1	$ 158.00	Schedule 4
Quality department (3 people)	Production	1	$ 144.00	Schedule 3
Team leader	Production	2	$ 30.00	Schedule 3

Table 3.2. *Resources*

The working hours for the business and personnel (these are independent of the different services) are as follows:

– MecaTools factory hours: Monday to Friday – 7:00 am to 8:00 pm (annual holidays: 25th July 2015 to 9th August 2015 inclusive);

– Schedule 1: Monday to Friday – 8 am to 12:30 pm and 1:30 pm to 6 pm;

– Schedule 2: Monday to Friday – 8 am to 12 pm and 1:30 pm to 5:30 pm;

– Schedule 3: Monday to Friday – 8 am to 12 pm and 1:30 pm to 5:30 pm;

– Schedule 4: Monday to Friday – 8 am to 12 pm and 2 pm to 5:30 pm.

The allocation of resources, determined by the project manager, is given in Table 3.3.

Name	Allocation
Project manager	A, B, C, G, N, O, P, T
Mechanical project assistant	A, B, D
Hydraulic project assistant	A, B, E
Computer automation project assistant	A, B, F
Design office (5 people)	B, C, G
Mechanical engineer	B, C, D, G, N, P, T
Electrotechnical engineer	B, C, F, I, J, K, N, P, T
Hydraulic engineer	B, C, E, H, N, P, T
Software engineer	B, C, F, J, L, M, N, O, P, T
Programmer 1	K, P
Programmer 2	L, P
Fitter 1	H, M, N, P
Fitter 2	G, H, N
Fitter 3	N, M
Fitter 4	J, M
Fitter 5	I, J
Technician 1	G, J, N, O, P
Technician 2	G, J, N, O, Q
Technician 3	I, M, P
Technician 4	I, M, Q, R
Secretary-editor	A, B, C, Q, R
Marketing (3 people)	S
Commercial services (3 people)	A, S, T
Logistics (2 people)	C, G, N
Quality control (3 people)	N, P, Q, S, T
Team leader 1	H, N
Team leader 2	I, N

Table 3.3. *Allocation*

The start date for the project is fixed as being 1st June 2015 at 8:00 am.

3.2.2. *Creating and configuring the project*

We will start by creating the project calendar, that is the factory hours – Monday to Friday, 7:00 am to 8:00 pm.

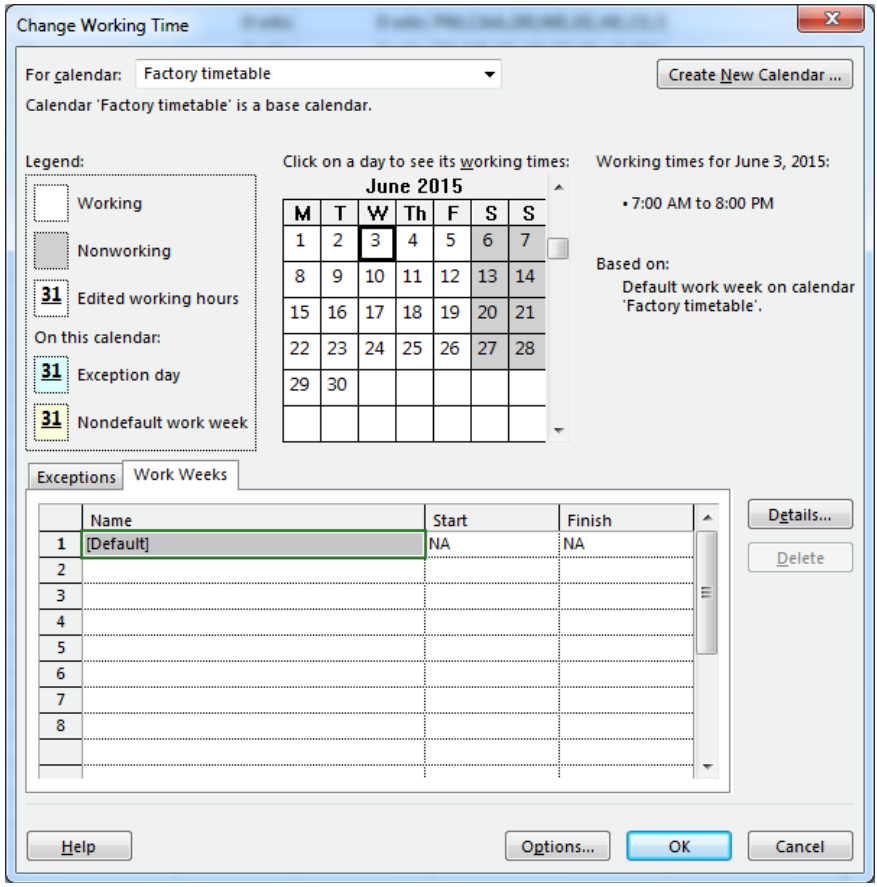


Figure 3.1. *Creating the "Factory schedule" calendar*

We will include the period where the factory is closed for annual holidays in the calendar exceptions, as well as public holidays (07/4/15, 9/7/15, 10/12/15, 11/11/15, 26/11/15, 12/25/15 and 01/01/16).

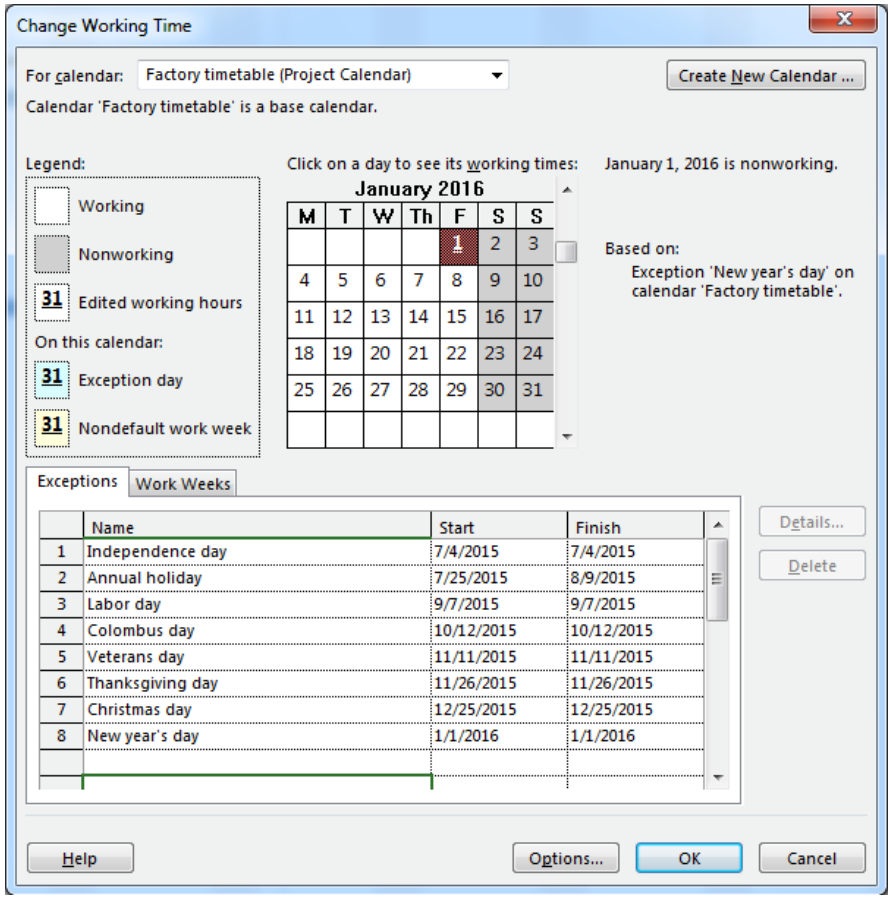


Figure 3.2. *The exceptions in the factory calendar*

We will also change the options:

– the week begins on a: Monday;

– default start time: 8:00 am;

– default finish time: 6:00 pm;

– hours per day: 7.5;

– hours per week: 37.5;

– days per month: 20.

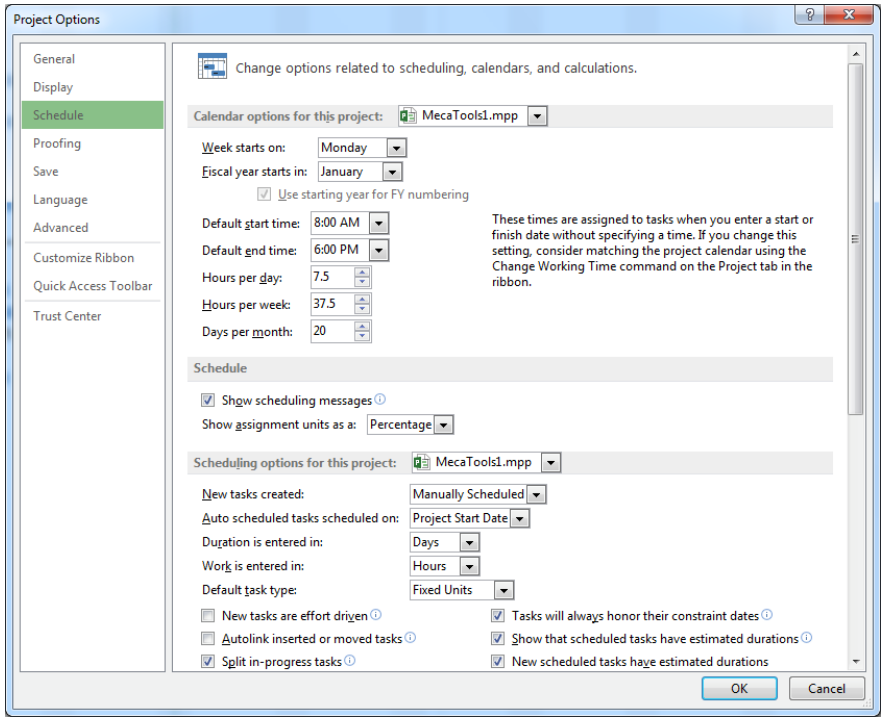


Figure 3.3. *The project calendar options*

We will now modify the project information, that is the start date and the calendar.

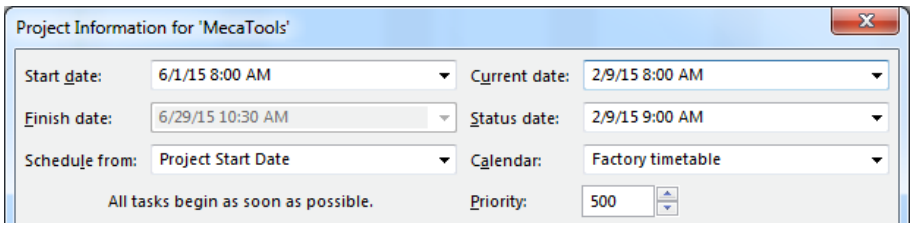


Figure 3.4. *Project information*

Once these parameters have been entered, we will save the project under "MecaTools.mpp".

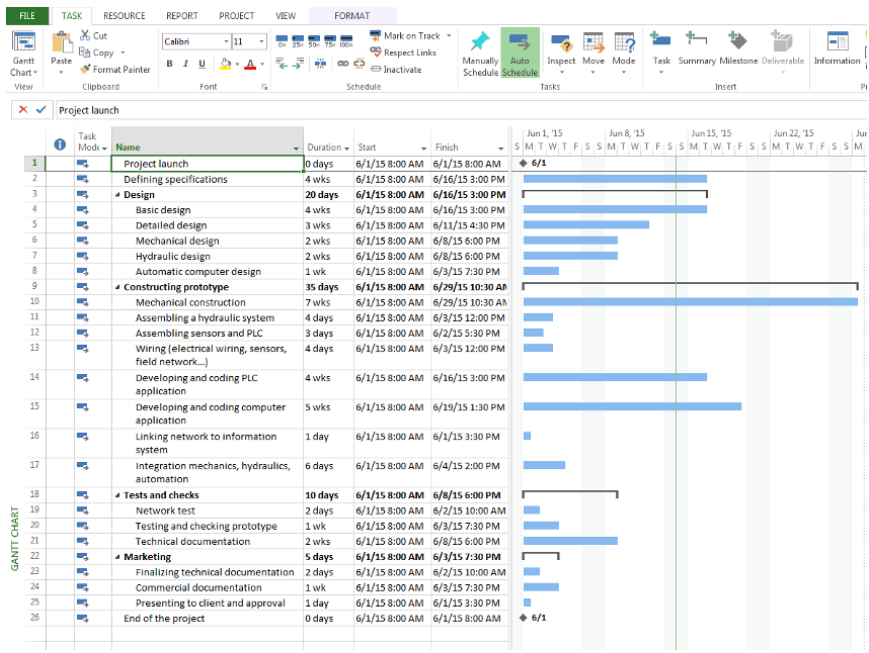
3.2.3. *Entering tasks and durations*

In addition to the tasks specified in the precedence table, we will add a "Project launch" task, with a duration of 0 days that will act as a start task as well as an "End of the project" task, also with a duration of 0 days, which will complete it.

Four main recap tasks are defined: "Design", "Prototype construction", "Tests and checks" and "Marketing", each containing several standard tasks. In order to carry out this work, the INDENT and OUTDENT TASKS functions in the ribbon will be used, found under the TASK tab in the SCHEDULE section.

The planning mode for tasks is set to "automatic mode" (TASK tab, TASKS section, AUTO SCHEDULE icon in the ribbon).

You can see the result obtained in Figure 3.5.



	Task Mode	Name	Duration	Start	Finish
1		Project launch	0 days	6/1/15 8:00 AM	6/1/15 8:00 AM
2		Defining specifications	4 wks	6/1/15 8:00 AM	6/16/15 3:00 PM
3		**Design**	**20 days**	**6/1/15 8:00 AM**	**6/16/15 3:00 PM**
4		Basic design	4 wks	6/1/15 8:00 AM	6/16/15 3:00 PM
5		Detailed design	3 wks	6/1/15 8:00 AM	6/11/15 4:30 PM
6		Mechanical design	2 wks	6/1/15 8:00 AM	6/8/15 6:00 PM
7		Hydraulic design	2 wks	6/1/15 8:00 AM	6/8/15 6:00 PM
8		Automatic computer design	1 wk	6/1/15 8:00 AM	6/3/15 7:30 PM
9		**Constructing prototype**	**35 days**	**6/1/15 8:00 AM**	**6/29/15 10:30 AM**
10		Mechanical construction	7 wks	6/1/15 8:00 AM	6/29/15 10:30 AM
11		Assembling a hydraulic system	4 days	6/1/15 8:00 AM	6/3/15 12:00 PM
12		Assembling sensors and PLC	3 days	6/1/15 8:00 AM	6/2/15 5:30 PM
13		Wiring (electrical wiring, sensors, field network...)	4 days	6/1/15 8:00 AM	6/3/15 12:00 PM
14		Developing and coding PLC application	4 wks	6/1/15 8:00 AM	6/16/15 3:00 PM
15		Developing and coding computer application	5 wks	6/1/15 8:00 AM	6/19/15 1:30 PM
16		Linking network to information system	1 day	6/1/15 8:00 AM	6/1/15 3:30 PM
17		Integration mechanics, hydraulics, automation	6 days	6/1/15 8:00 AM	6/4/15 2:00 PM
18		**Tests and checks**	**10 days**	**6/1/15 8:00 AM**	**6/8/15 6:00 PM**
19		Network test	2 days	6/1/15 8:00 AM	6/2/15 10:00 AM
20		Testing and checking prototype	1 wk	6/1/15 8:00 AM	6/3/15 7:30 PM
21		Technical documentation	2 wks	6/1/15 8:00 AM	6/8/15 6:00 PM
22		**Marketing**	**5 days**	**6/1/15 8:00 AM**	**6/3/15 7:30 PM**
23		Finalizing technical documentation	2 days	6/1/15 8:00 AM	6/2/15 10:00 AM
24		Commercial documentation	1 wk	6/1/15 8:00 AM	6/3/15 7:30 PM
25		Presenting to client and approval	1 day	6/1/15 8:00 AM	6/1/15 3:30 PM
26		End of the project	0 days	6/1/15 8:00 AM	6/1/15 8:00 AM

Figure 3.5. *The main recap tasks and traditional tasks entered into Microsoft Project*

It might seem strange that the length for a task such as "Design" is automatically calculated at 20 days (recap task) despite the fact that it starts on 06/01/15 at 8:00 am and finishes on 06/16/15 at 3:00 pm, slightly fewer than 16 calendar days.

The same applies for other tasks where the duration has been manually entered. For example, the "Assembling sensors and PLC" task has a duration of three days but starts on 06/01/15 at 8:00 am and ends on 06/02/15, just less than two calendar days.

In reality, this is no error. Our project calendar "Factory schedule" features a working day (see Figure 3.2) that starts at 7:00 am and finishes at 8:00 pm, which is 13 hours long. If we look again at our two tasks, we can calculate by looking at the default options in Figure 3.3, which gives 7.5 h per day:

– "Design": 20 days, therefore *(20 × 7.5)/13 ≈ 11.538d = 11d +) 0.538d = 11d + 0.538 × 13 ≈ 11d + 7h* to which we will add four unworked days (two Saturdays + two Sundays), or *11d + 4d + 7h = 15d +7h*. We can verify (with working days starting at 8am): *06/01/15 8:00 am + 15d 7h = 06/16/15 3:00 pm*;

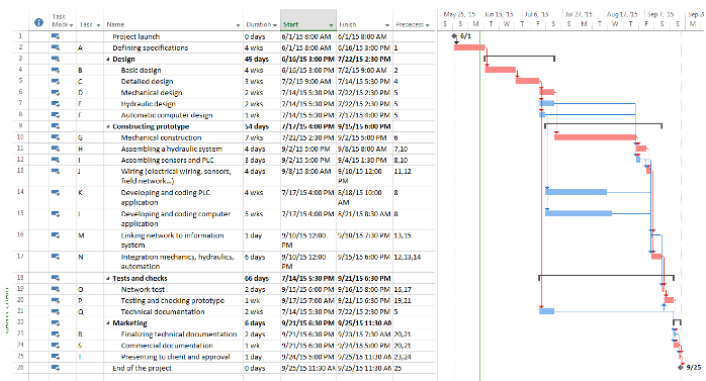
– "Assembling sensors and PLC": three days, therefore *(3 × 7.5)/13 ≈ 1.73d = 1d + 0.73d = 1d + 0.73 × 13 ≈ 1d + 9.5 h.* We can verify (with working days starting at 8 am): *06/01/15 8:00 am + 1d 9.5h = 06/02/15 5:30 pm*.

3.2.4. *Entering predecessors*

We will continue building our project by adding the antecedents for each of the tasks.

A Task column (Text1) can be added to allow us to note the letters corresponding to the different tasks and to make it easier to input predecessors.

Once completed, this will give us the table and the Gantt chart shown in Figure 3.6.



	Task Mode	Task	Name	Duration	Start	Finish	Predecess
1			Project launch	0 days	6/1/15 8:00 AM	6/1/15 8:00 AM	
2		A	Defining specifications	4 wks	6/1/15 8:00 AM	6/30/15 3:00 PM	1
3			◢ Design	45 days	6/16/15 3:00 PM	7/22/15 2:30 PM	
4		B	Basic design	4 wks	6/16/15 3:00 PM	7/15/15 9:00 AM	2
5		C	Detailed design	3 wks	7/2/15 9:00 AM	7/14/15 5:30 PM	4
6		D	Mechanical design	2 wks	7/14/15 5:30 PM	7/22/15 2:30 PM	5
7		E	Hydraulic design	2 wks	7/14/15 5:30 PM	7/22/15 2:30 PM	5
8		F	Automatic computer design	1 wk	7/14/15 5:30 PM	7/21/15 8:00 PM	5
9			◢ Constructing prototype	54 days	7/1/15 8:00 PM	9/15/15 8:00 PM	
10		G	Mechanical construction	7 wks	7/22/15 2:30 PM	9/2/15 3:00 PM	8
11		H	Assembling a hydraulic system	4 days	9/2/15 3:00 PM	9/8/15 8:00 AM	7,10
12		I	Assembling sensors and PLC	3 days	9/2/15 3:00 PM	9/4/15 1:30 PM	8,10
13		J	Wiring (electrical wiring, sensors, field network...)	4 days	9/8/15 8:00 AM	9/10/15 12:00 PM	11,12
14		K	Developing and coding PLC application	4 wks	7/17/15 4:00 PM	8/18/15 10:00 AM	8
15		L	Developing and coding computer application	5 wks	7/17/15 4:00 PM	8/21/15 8:30 AM	8
16		M	Linking network to information system	1 day	9/10/15 12:00 PM	9/10/15 7:30 PM	13,15
17		N	Integration mechanics, hydraulics, automation	6 days	9/10/15 12:00 PM	9/15/15 8:00 PM	12,13,14
18			◢ Tests and checks	06 days	7/14/15 5:30 PM	9/21/15 6:30 PM	
19		O	Network test	2 days	9/15/15 8:00 PM	9/16/15 8:00 PM	16,17
20		P	Testing and checking prototype	1 wk	9/17/15 7:00 AM	9/21/15 6:30 PM	19,21
21		Q	Technical documentation	2 wks	7/14/15 5:30 PM	7/22/15 2:30 PM	5
22			◢ Marketing	6 days	9/15/15 6:30 PM	9/25/15 11:30 AM	
23		R	Finalizing technical documentation	2 days	9/21/15 6:30 PM	9/23/15 7:30 AM	20,21
24		S	Commercial documentation	1 wk	9/21/15 6:30 PM	9/28/15 5:00 PM	20,21
25		T	Presenting to client and approval	1 day	9/24/15 5:00 PM	9/25/15 11:30 AM	23,24
26			End of the project	0 days	9/25/15 11:30 AM	9/25/15 11:30 AM	25

Figure 3.6. *The table featuring the filled "Task" and "Antecedents" columns*

3.2.5. *MPM network visualization*

It is possible to visualize this whole project using an MPM network via the NETWORK DIAGRAM icon in the ribbon, under VIEW.

In this display mode, it is also possible to make modifications to the network, particularly relating to adding or deleting eventual links.

Using the zoom functions makes it possible to see certain sections of the network in greater detail. The visible data may vary, by default, but it will include the name of the task, the start date, the end date, its number, its duration and its resources, if they have been allocated.

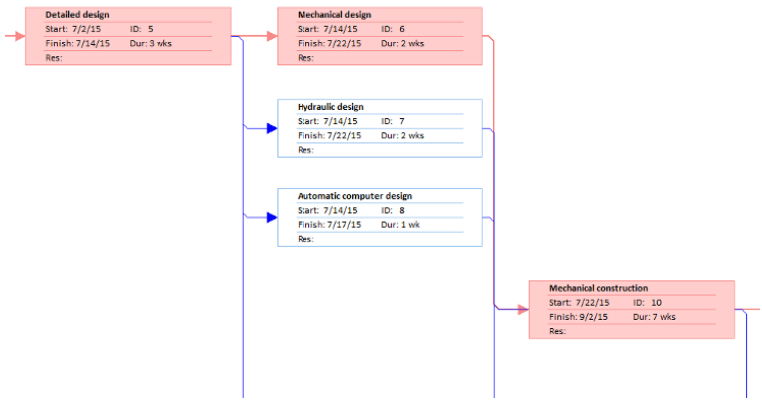


Figure 3.7. *A detailed look at some tasks from the "MecaTools" project*

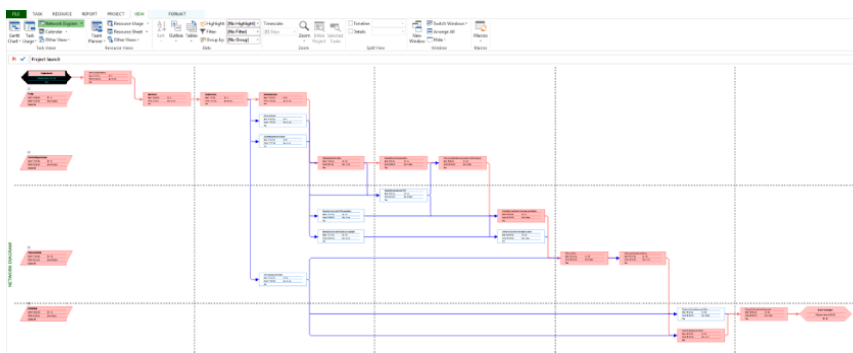


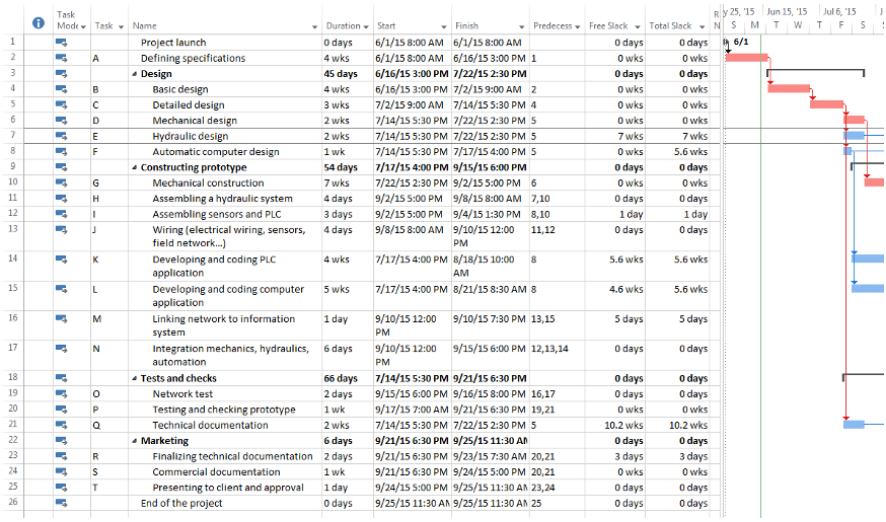
Figure 3.8. *The MPM network (or task network) corresponding to the "MecaTools" project*

The dotted lines mark the page edges (depending on the default printer settings) and indicate how it will be divided during printing. In our example, the network will be spread across 15 A4 pages.

3.2.6. *Calculating slacks*

With Microsoft Project, calculating slack is straightforward – all that is required is to complete the table to the left of the Gantt chart with columns for "Free slack" and "Total slack".

These are expressed by default in units similar to those used for duration.



	Task Mode	Task	Name	Duration	Start	Finish	Predecess	Free Slack	Total Slack
1			Project launch	0 days	6/1/15 8:00 AM	6/1/15 8:00 AM		0 days	0 days
2		A	Defining specifications	4 wks	6/1/15 8:00 AM	6/16/15 3:00 PM	1	0 wks	0 wks
3			**Design**	**45 days**	**6/16/15 3:00 PM**	**7/22/15 2:30 PM**		**0 days**	**0 days**
4		B	Basic design	4 wks	6/16/15 3:00 PM	7/2/15 9:00 AM	2	0 wks	0 wks
5		C	Detailed design	3 wks	7/2/15 9:00 AM	7/14/15 5:30 PM	4	0 wks	0 wks
6		D	Mechanical design	2 wks	7/14/15 5:30 PM	7/22/15 2:30 PM	5	0 wks	0 wks
7		E	Hydraulic design	2 wks	7/14/15 5:30 PM	7/22/15 2:30 PM	5	7 wks	7 wks
8		F	Automatic computer design	1 wk	7/14/15 5:30 PM	7/17/15 4:00 PM	5	0 wks	5.6 wks
9			**Constructing prototype**	**54 days**	**7/17/15 4:00 PM**	**9/15/15 6:00 PM**		**0 days**	**0 days**
10		G	Mechanical construction	7 wks	7/22/15 2:30 PM	9/2/15 5:00 PM	6	0 wks	0 wks
11		H	Assembling a hydraulic system	4 days	9/2/15 5:00 PM	9/8/15 8:00 AM	7,10	0 days	0 days
12		I	Assembling sensors and PLC	3 days	9/2/15 5:00 PM	9/4/15 1:30 PM	8,10	1 day	1 day
13		J	Wiring (electrical wiring, sensors, field network...)	4 days	9/8/15 8:00 AM	9/10/15 12:00 PM	11,12	0 days	0 days
14		K	Developing and coding PLC application	4 wks	7/17/15 4:00 PM	8/18/15 10:00 AM	8	5.6 wks	5.6 wks
15		L	Developing and coding computer application	5 wks	7/17/15 4:00 PM	8/21/15 8:30 AM	8	4.6 wks	5.6 wks
16		M	Linking network to information system	1 day	9/10/15 12:00 PM	9/10/15 7:30 PM	13,15	5 days	5 days
17		N	Integration mechanics, hydraulics, automation	6 days	9/10/15 12:00 PM	9/15/15 6:00 PM	12,13,14	0 days	0 days
18			**Tests and checks**	**66 days**	**7/14/15 5:30 PM**	**9/21/15 6:30 PM**		**0 days**	**0 days**
19		O	Network test	2 days	9/15/15 6:00 PM	9/16/15 8:00 PM	16,17	0 days	0 days
20		P	Testing and checking prototype	1 wk	9/17/15 7:00 AM	9/21/15 6:30 PM	19,21	0 wks	0 wks
21		Q	Technical documentation	2 wks	7/14/15 5:30 PM	7/22/15 2:30 PM	5	10.2 wks	10.2 wks
22			**Marketing**	**6 days**	**9/21/15 6:30 PM**	**9/25/15 11:30 AM**		**0 days**	**0 days**
23		R	Finalizing technical documentation	2 days	9/21/15 6:30 PM	9/23/15 7:30 AM	20,21	3 days	3 days
24		S	Commercial documentation	1 wk	9/21/15 6:30 PM	9/24/15 5:00 PM	20,21	0 wks	0 wks
25		T	Presenting to client and approval	1 day	9/24/15 5:00 PM	9/25/15 11:30 AM	23,24	0 days	0 days
26			End of the project	0 days	9/25/15 11:30 AM	9/25/15 11:30 AM	25	0 days	0 days

Figure 3.9. *The table, to the left of the Gantt chart, to which the two columns: "Free slack" and "Total slack" have been added*

It is also possible to show slack on a Gantt chart by configuring style bars.

We will now move on to entering resources in the Microsoft Project resources table.

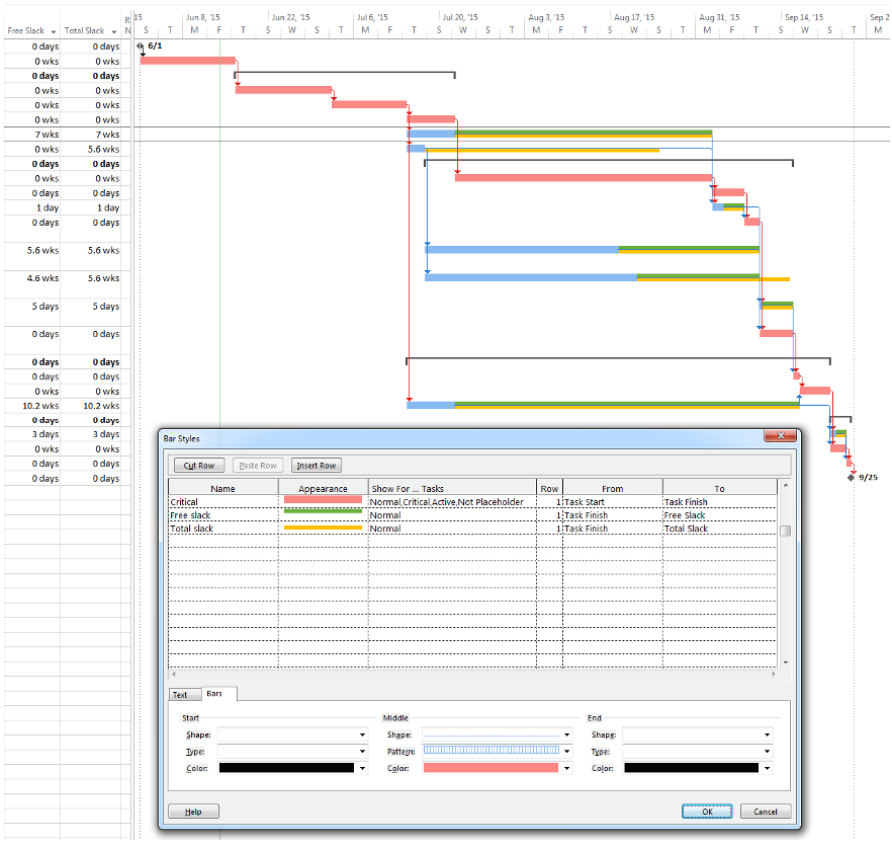


Figure 3.10. *The Gantt chart showing free and total slack. Below is shown the window for configuring style bars*

3.2.7. *Entering resources*

Before entering resources, we will need to create the necessary calendars, “Timetable 1” to “Timetable 4” (see section 3.2.1).

To make it easier to create, we can copy elements of the calendar from the “Factory timetable” calendar, which will allow us to keep public holidays and the annual holiday period.

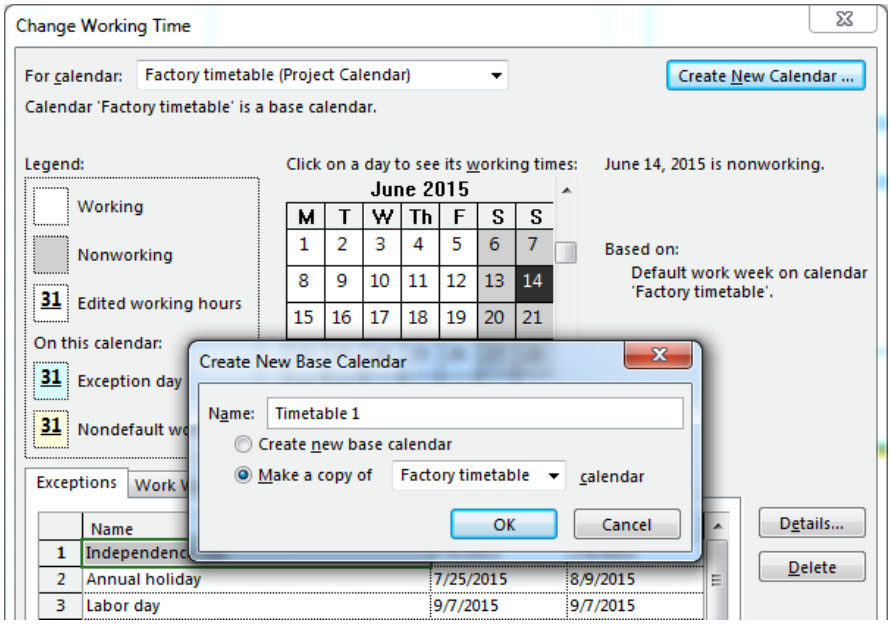


Figure 3.11. *Creating resource calendars using a copy of the "Factory schedule" calendar*

When several resources have the same function, we will differentiate them and each of them will be represented on a single row.

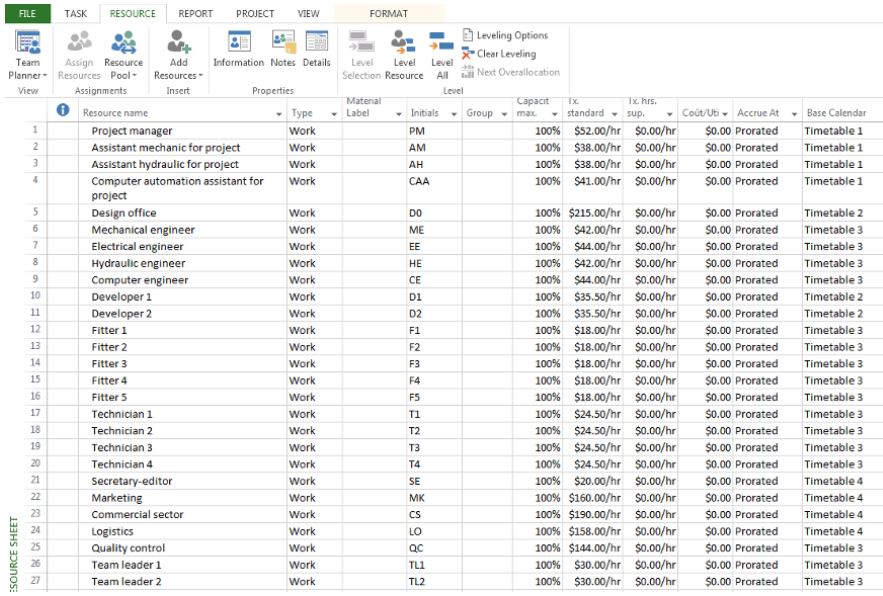
By default, if no capacity is given, each of the resources is considered as working at 100% on the project.

The value of the capacity is often linked to the fact that a resource can be shared between several projects and can therefore have a capacity of somewhere between 0 and 100% for any given project.

The design brief did not specify any hourly rate for overtime and so one hasn't been entered.

As with the majority of cases, when we are dealing with a labor resource, the allocation of cost is proportionate (to the time spent on the project).

Figure 3.12 shows the resources table.



	Resource name	Type	Material Label	Initials	Group	Capacit max.	Tx. standard	Tx. hrs. sup.	Coût/Uti	Accrue At	Base Calendar
1	Project manager	Work		PM		100%	$52.00/hr	$0.00/hr	$0.00	Prorated	Timetable 1
2	Assistant mechanic for project	Work		AM		100%	$38.00/hr	$0.00/hr	$0.00	Prorated	Timetable 1
3	Assistant hydraulic for project	Work		AH		100%	$38.00/hr	$0.00/hr	$0.00	Prorated	Timetable 1
4	Computer automation assistant for project	Work		CAA		100%	$41.00/hr	$0.00/hr	$0.00	Prorated	Timetable 1
5	Design office	Work		D0		100%	$215.00/hr	$0.00/hr	$0.00	Prorated	Timetable 2
6	Mechanical engineer	Work		ME		100%	$42.00/hr	$0.00/hr	$0.00	Prorated	Timetable 3
7	Electrical engineer	Work		EE		100%	$44.00/hr	$0.00/hr	$0.00	Prorated	Timetable 3
8	Hydraulic engineer	Work		HE		100%	$42.00/hr	$0.00/hr	$0.00	Prorated	Timetable 3
9	Computer engineer	Work		CE		100%	$44.00/hr	$0.00/hr	$0.00	Prorated	Timetable 3
10	Developer 1	Work		D1		100%	$35.50/hr	$0.00/hr	$0.00	Prorated	Timetable 2
11	Developer 2	Work		D2		100%	$35.50/hr	$0.00/hr	$0.00	Prorated	Timetable 2
12	Fitter 1	Work		F1		100%	$18.00/hr	$0.00/hr	$0.00	Prorated	Timetable 3
13	Fitter 2	Work		F2		100%	$18.00/hr	$0.00/hr	$0.00	Prorated	Timetable 3
14	Fitter 3	Work		F3		100%	$18.00/hr	$0.00/hr	$0.00	Prorated	Timetable 3
15	Fitter 4	Work		F4		100%	$18.00/hr	$0.00/hr	$0.00	Prorated	Timetable 3
16	Fitter 5	Work		F5		100%	$18.00/hr	$0.00/hr	$0.00	Prorated	Timetable 3
17	Technician 1	Work		T1		100%	$24.50/hr	$0.00/hr	$0.00	Prorated	Timetable 3
18	Technician 2	Work		T2		100%	$24.50/hr	$0.00/hr	$0.00	Prorated	Timetable 3
19	Technician 3	Work		T3		100%	$24.50/hr	$0.00/hr	$0.00	Prorated	Timetable 3
20	Technician 4	Work		T4		100%	$24.50/hr	$0.00/hr	$0.00	Prorated	Timetable 3
21	Secretary-editor	Work		SE		100%	$20.00/hr	$0.00/hr	$0.00	Prorated	Timetable 4
22	Marketing	Work		MK		100%	$160.00/hr	$0.00/hr	$0.00	Prorated	Timetable 4
23	Commercial sector	Work		CS		100%	$190.00/hr	$0.00/hr	$0.00	Prorated	Timetable 4
24	Logistics	Work		LO		100%	$158.00/hr	$0.00/hr	$0.00	Prorated	Timetable 4
25	Quality control	Work		QC		100%	$144.00/hr	$0.00/hr	$0.00	Prorated	Timetable 3
26	Team leader 1	Work		TL1		100%	$30.00/hr	$0.00/hr	$0.00	Prorated	Timetable 3
27	Team leader 2	Work		TL2		100%	$30.00/hr	$0.00/hr	$0.00	Prorated	Timetable 3

Figure 3.12. *The resources table*

It should be noted that this table gives initials that will be useful a bit later on when displaying resources on the Gantt chart.

3.2.8. *Allocating resources*

We will now specify what resources will be allocated to each of the tasks.

The program will automatically recalculate the data depending on the constraints imposed (schedule, cost, slack, charges, potential over-use, etc.).

To make the allocations, we will use the RESOURCE NAMES column in the Gantt chart view.

The RESOURCE INITIALS column has been added and it will be displayed behind each bar in the chart.

	Task Mode	Task	Name	Duration	Start	Finish	Predecess	Free Slack	Total Slack	Resource Names	Resource Initials
1			Project launch	0 days	6/1/15 8:00 AM	6/1/15 8:00 AM		0 days	0 days		
2		A	Defining specifications	5.33 wks	6/1/15 8:00 AM	7/2/15 10:30 AM	1	0 wks	0 wks	Assistant hydraulic for p	AH,AM,CAA,PM,SE,
3			**Design**	**99.73 days**	**7/2/15 10:30 AM**	**10/6/15 5:30 PM**		**0 days**	**0 days**		
4		B	Basic design	7.79 wks	7/2/15 10:30 AM	8/28/15 11:00 AM	2	0 wks	0 wks	Project manager,Compu	PM,CAA,D0,ME,EE,I
5		C	Detailed design	4.41 wks	8/28/15 11:00 AM	9/24/15 9:30 AM	4	0 wks	0 wks	Design office,Mechanics	D0,ME,EE,HE,CE,SE,
6		D	Mechanical design	2.23 wks	9/24/15 9:30 AM	10/6/15 5:30 PM	5	0 wks	0 wks	Assistant mechanic for p	AM,ME
7		E	Hydraulic design	2.23 wks	9/24/15 9:30 AM	10/6/15 5:30 PM	5	18.89 wks	18.89 wks	Assistant hydraulic for p	AH,HE
8		F	Automatic computer design	1.21 wks	9/24/15 9:30 AM	10/1/15 8:30 AM	5	0 wks	16.17 wks	Computer automation a	CAA,EE,CE
9			**Constructing prototype**	**137.13 day**	**10/1/15 8:30 AM**	**1/22/16 10:00 AM**		**0 days**	**0 days**		
10		G	Mechanical construction	12.91 wks	10/6/15 5:30 PM	12/28/15 2:30 PM	6	0 wks	0 wks	Project manager,Design	PM,D0,ME,F2,T1,T2
11		H	Assembling a hydraulic system	4 days	12/28/15 2:30 PM	1/4/16 9:30 AM	7,10	0 days	0 days	Hydraulic engineer, Fitter 1,Fitter 2,Team	HE,F1,F2,TL1
12		I	Assembling sensors and PLC	3 days	12/28/15 2:30 PM	12/31/15 10:30 AM	8,10	1.6 days	1.6 days	Electrical engineer, Fitter 5,Technician 3,Tec	EE,F5,T3,T4,TL2,F4
13		J	Wiring (electrical wiring, sensors, field network...)	4 days	1/4/16 9:30 AM	1/7/16 3:00 PM	11,12	0 days	0 days	Electrical engineer, Computer engineer,Fitt	EE,CE,F4,F5,T1,T2
14		K	Developing and coding PLC application	4.24 wks	10/1/15 8:30 AM	10/28/15 4:00 PM	8	16.17 wks	16.17 wks	Electrical engineer, Developer 1	EE,D1
15		L	Developing and coding computer application	5.29 wks	10/1/15 8:30 AM	11/4/15 12:00 PM	8	14.64 wks	18.95 wks	Computer engineer, Developer 2	CE,D2
16		M	Linking network to information system	1 day	1/7/16 3:00 PM	1/8/16 2:00 PM	13,15	22 days	22 days	Computer engineer, Fitter 1,Fitter 3,Technici	CE,F1,F3,T3,T4
17		N	Integration mechanics, hydraulics, automation	16 days	1/7/16 3:00 PM	1/27/16 10:00 AM	12,13,14	0 days	0 days	Project manager, Mechanical engineer,Ele	PM,ME,EE,HE,CE,F1
18			**Tests and checks**	**166.47 day**	**9/24/15 9:30 AM**	**2/12/16 10:00 AM**		**0 days**	**0 days**		
19		O	Network test	2.87 days	1/27/16 10:00 AM	1/29/16 2:00 PM	16,17	0 days	0 days	Project manager,Mecha	PM,ME,CE,T1,T2
20		P	Testing and checking prototype	2.29 wks	1/29/16 2:00 PM	2/12/16 10:00 AM	19,21	0 wks	0 wks	Project manager, Electrical engineer,Hydr	PM,EE,HE,CE,D1,D2
21		Q	Technical documentation	2,24 wks	9/24/15 9:30 AM	10/8/15 9:30 AM	5	26.47 wks	26.47 wks	Technician 2,Technician	T2,T4,SE
22			**Marketing**	**11.2 days**	**2/12/16 10:00 AM**	**2/22/16 4:00 PM**		**0 days**	**0 days**		
23		R	Finalizing technical documentation	2.27 days	2/12/16 10:00 AM	2/16/16 10:00 AM	20,21	5.2 days	5.2 days	Technician 4, Secretary-editor	T4,SE
24		S	Commercial documentation	1.13 wks	2/12/16 10:00 AM	2/19/16 10:00 AM	20,21	0 wks	0 wks	Marketing,Commercial s	MK,CS,QC
25		T	Presenting to client and approval	1.93 days	2/19/16 10:00 AM	2/22/16 4:00 PM	23,24	0 days	0 days	Project manager, Mechanical engineer,Ele	PM,ME,EE,HE,CE,CS
26			End of the project	0 days	2/22/16 4:00 PM	2/22/16 4:00 PM	25	0 days	0 days		

Figure 3.13. *The table with the "Resource names" and "Resource initials" columns*

In Figure 3.13, note that task durations have been calculated as well as dates. The same applies for the free and total slack.

In the indicators Column i on the left, we notice small logos in the shape of red characters marking several rows (tasks G, J, M, N and Q). Their role is to indicate over-allocation of resources. These problems will need to be resolved in order to maintain a consistent project while trying to keep within the restrictions.

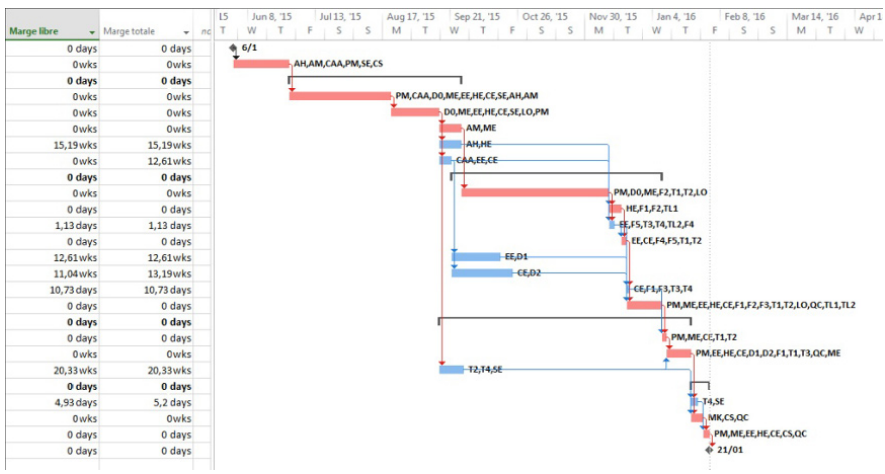


Figure 3.14. *The new slack calculated and the Gantt chart showing resource initials*

It is rare to have a complex project without detecting evidence of over-allocation. Microsoft Project has a number of tools to resolve these issues.

3.2.9. *Resolving over-allocations*

In order to solve the problem posed by over-allocations, there are a range of solutions available:

– rescheduling the task for the next date the resource is available;

– replacing this resource with another available resource that can perform the same work;

– taking on another resource to carry out the work (add a resource);

– rescheduling the task by adjusting the slack.

Using the Team Planner or the resource use table, we can examine the periods of over allocation for each resource in detail. These are outlined in red, across from each of the relevant resources. The time axis located in the upper part allows us to determine the dates and the periods for which the normal workload has been exceeded (linked to the schedule that the resource has to follow).

In our example, in Figure 3.15, we can see an over-allocation for the "Computer engineer", "Fitter 1", "Fitter 3" and "Technician 2" resources.

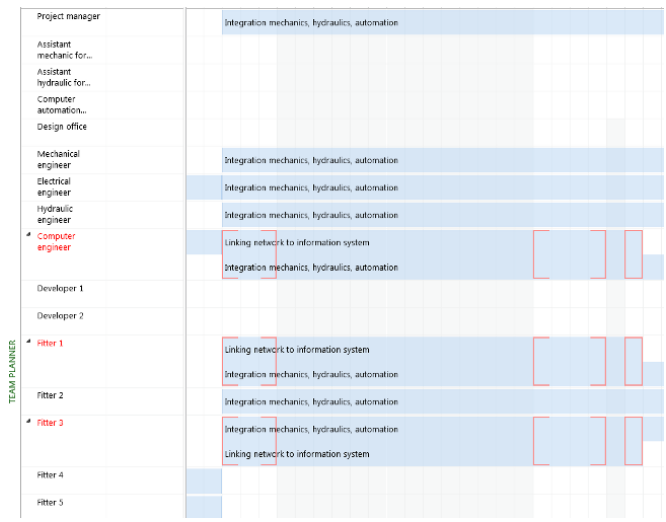


Figure 3.15. *The team planner. We can see the periods of over-allocation for the "Computer engineer", "Fitter 1" and "Fitter 3" resources*

For the first three, the time intervals where there is an over-allocation are as follows:

– Monday 12/28 from 10:00 am to 11:00 am and 1:00 pm to 5:00 pm;

– Tuesday 12/29 from 8:00 am to 9:00 am.

On the resource use table, we can see these same over-allocations in more detail, along with the actual number of work hours to be carried out.

RESOURCE USAGE

		Presenting to client and approval	*9 hrs*	Work							
9	◆	**Computer engineer**	**734.5 hrs**	Work		7h	8.5h	8.5h	11h	13.5h	
		Basic design	*216 hrs*	Work							
		Detailed design	*119.5 hrs*	Work							
		Automatic computer design	*41.5 hrs*	Work							
		Wiring (electrical wiring, sensors, field network...)	*30 hrs*	Work		7h	8.5h	8.5h	6h		
		Developing and coding computer application	*187.5 hrs*	Work							
		Linking network to information system	*7.5 hrs*	Work					2.5h	5h	
		Integration mechanics, hydraulics, automation	*60 hrs*	Work					2.5h	8.5h	
		Network test	*17 hrs*	Work							
		Testing and checking prototype	*46 hrs*	Work							
		Presenting to client and approval	*9.5 hrs*	Work							
10		Developer 1	200.5 hrs	Work							
		Developing and coding PLC application	*150 hrs*	Work							
		Testing and checking prototype	*50.5 hrs*	Work							
11		Developer 2	245.5 hrs	Work							
		Developing and coding computer application	*187.5 hrs*	Work							
		Testing and checking prototype	*58 hrs*	Work							
12	◆	**Fitter 1**	**167.5 hrs**	Work		1.5h			5h	13.5h	
		Assembling a hydraulic system	*30 hrs*	Work		1.5h					
		Linking network to information system	*7.5 hrs*	Work					2.5h	5h	
		Integration mechanics, hydraulics, automation	*65 hrs*	Work					2.5h	8.5h	
		Testing and checking prototype	*65 hrs*	Work							
13		Fitter 2	421 hrs	Work		1.5h			2.5h	8.5h	
		Mechanical construction	*321 hrs*	Work							
		Assembling a hydraulic system	*30 hrs*	Work		1.5h					
		Integration mechanics, hydraulics, automation	*70 hrs*	Work					2.5h	8.5h	
14	◆	**Fitter 3**	**82.5 hrs**	Work					5h	13.5h	
		Linking network to information system	*7.5 hrs*	Work					2.5h	5h	
		Integration mechanics, hydraulics, automation	*75 hrs*	Work					2.5h	8.5h	
15		Fitter 4	52.5 hrs	Work		7h	8.5h	8.5h	6h		
		Assembling sensors and PLC	*22.5 hrs*	Work							
		Wiring (electrical wiring, sensors, field network...)	*30 hrs*	Work		7h	8.5h	8.5h	6h		

Figure 3.16. *The resource use table featuring the number of hours for each resource*

By configuring the display, we can obtain other information. This is shown in Figure 3.17, where, for each resource and each task, the following elements will appear: “Work”, “Over-allocation”, “Cost”, and “Remaining availability”.

We will remove our “software engineer”, from task no. 13, “Wiring (electrical, sensors, field network, etc.)” because, following a discussion with their colleagues, it turns out that the same work can be carried out without them.

Once this has been removed, the over-allocation for task no. 13 will disappear.

In task no. 21, “Technical documentation”, we will replace “Technician 2” with “Technician 3” who can carry out the same work and who is available on that date.

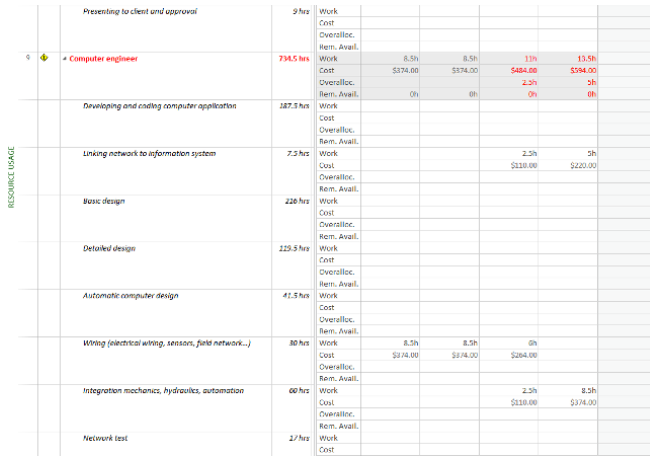


Figure 3.17. *A more detailed display showing the resource use table*

As a result, the over-allocation for task no. 10, “Mechanical construction” will disappear. Indeed, “Technician 2” was also used during this same period and can now focus exclusively on this task.

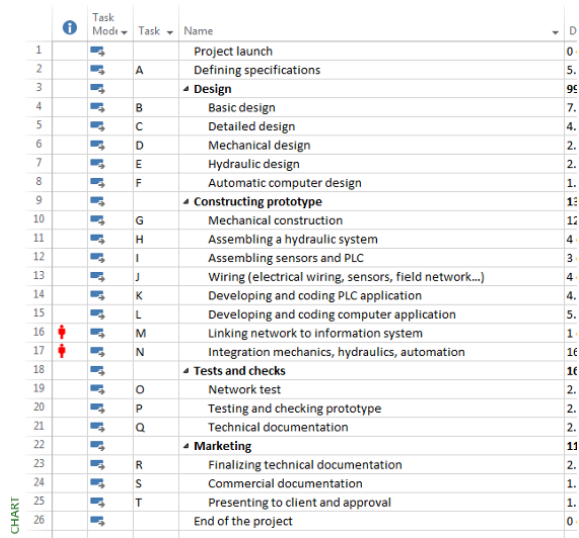
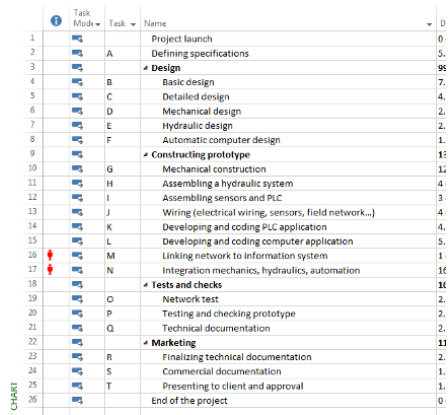


Figure 3.18. *The over-allocations in tasks no. 10, 13 and 21 have disappeared*

There are now only two tasks left showing over-allocation: no. 16, “Network computer system” and no. 17, “Mechanical, hydraulic, computer integration”.

“Computer engineer”, “Fitter 1” and “Fitter 3” are the over-allocated resources. In order to solve this problem, we will ask the program to reschedule task no. 16 for the next available date (Figure 3.19).

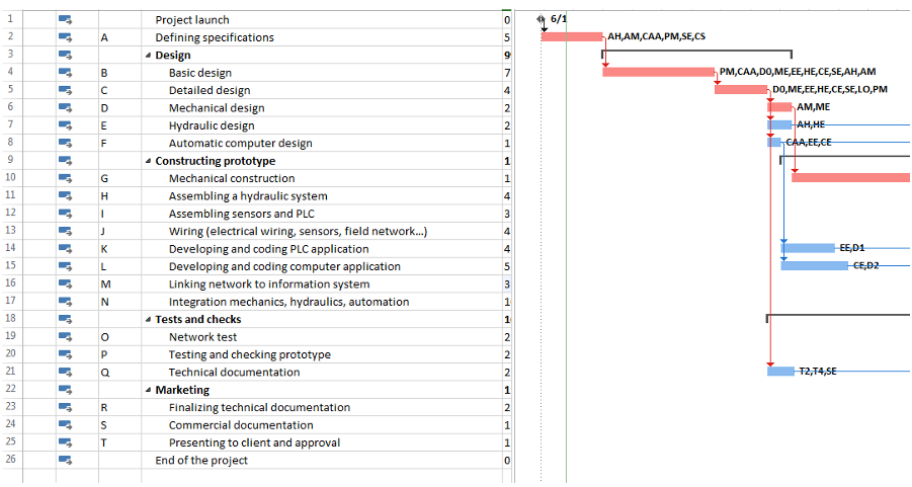


	Task Mode	Task	Name	D
1			Project launch	0
2		A	Defining specifications	5.
3			**Design**	9
4		B	Basic design	7.
5		C	Detailed design	4.
6		D	Mechanical design	2.
7		E	Hydraulic design	2.
8		F	Automatic computer design	1.
9			**Constructing prototype**	1
10		G	Mechanical construction	1
11		H	Assembling a hydraulic system	4
12		I	Assembling sensors and PLC	3
13		J	Wiring (electrical wiring, sensors, field network...)	4
14		K	Developing and coding PLC application	4.
15		L	Developing and coding computer application	5.
16		M	Linking network to information system	1
17		N	Integration mechanics, hydraulics, automation	1
18			**Tests and checks**	1
19		O	Network test	2.
20		P	Testing and checking prototype	2.
21		Q	Technical documentation	2.
22			**Marketing**	1
23		R	Finalizing technical documentation	2.
24		S	Commercial documentation	1.
25		T	Presenting to client and approval	1.
26			End of the project	0

CHART

Figure 3.19. *Rescheduling task no. 16 for the next available date*

Once this operation has been carried out, everything is as it should be, and there is no longer any over-allocation.



1			Project launch	0
2		A	Defining specifications	5
3			**Design**	9
4		B	Basic design	7
5		C	Detailed design	4
6		D	Mechanical design	2
7		E	Hydraulic design	2
8		F	Automatic computer design	1
9			**Constructing prototype**	1
10		G	Mechanical construction	1
11		H	Assembling a hydraulic system	4
12		I	Assembling sensors and PLC	3
13		J	Wiring (electrical wiring, sensors, field network...)	4
14		K	Developing and coding PLC application	4
15		L	Developing and coding computer application	5
16		M	Linking network to information system	3
17		N	Integration mechanics, hydraulics, automation	1
18			**Tests and checks**	1
19		O	Network test	2
20		P	Testing and checking prototype	2
21		Q	Technical documentation	2
22			**Marketing**	1
23		R	Finalizing technical documentation	2
24		S	Commercial documentation	1
25		T	Presenting to client and approval	1
26			End of the project	0

Figure 3.20. *There are no remaining over-allocated tasks*

We can now consider this project to have been properly scheduled.

3.2.10. *Viewing the project timeline*

In order to obtain a more general view of the "MecaTools" project, it is possible to attach a simple or more detailed timeline to the project.

For our example, we have chosen to put the recap tasks in legend form (above the time axis) and to display the other tasks in detail.

The critical tasks have been differentiated using different background colors.

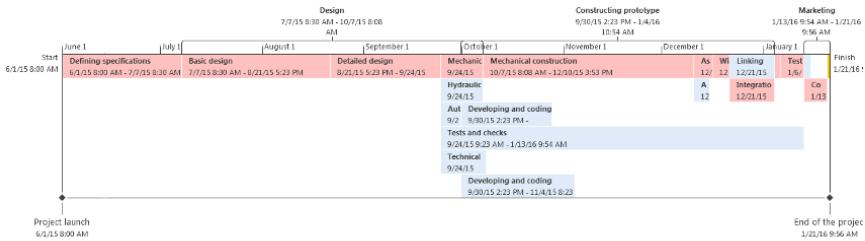


Figure 3.21. *The detailed timeline for the "MecaTools" project*

3.2.11. *Using WBS coding*

The Work Breakdown Structure (WBS) is a means by which we can divide a project hierarchically with the tasks broken down into different levels. Today, this is often referred to as a project management flowchart.

It was the US Department of Defense who developed this concept in the 1950s before it was later adopted by various companies.

Its aim is to make project organization easier.

With Microsoft Project, we can use a form of coding based on the WBS principle, which can also be personalized. Its structure is based on an initial main code that represents the project itself by default.

For our "MecaTools" project, we will create a code whose main prefix will be "1", followed by a series of ordered numbers.

Using the WBS tool from the ribbon, under the PROJECT tab, we will create the code structure (Figure 3.22).

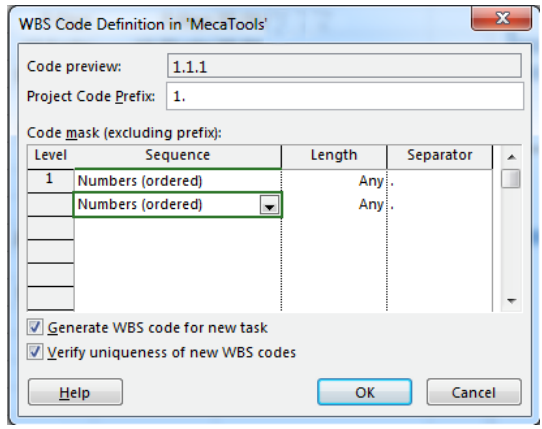


Figure 3.22. *The window for creating the WBS code structure*

Next, we will add a WBS column in the table linked to the Gantt chart.

	Task Mode	WBS	Task	Name	Duration	Start	Finish	Predecess
1		1.1		Project launch	0 days	6/1/15 8:0(	6/1/15 8:0(	
2		1.2	A	Defining specifications	5.88 wks	6/1/15 8:0(	7/7/15 8:3(	1
3		**1.3**		**Design**	**95.28 days**	**7/7/15 8:3(**	**10/7/15 8:(**	
4		1.3.1	B	Basic design	6.05 wks	7/7/15 8:3(	8/21/15 5::	2
5		1.3.2	C	Detailed design	5.28 wks	8/21/15 5::	9/24/15 9::	4
6		1.3.3	D	Mechanical design	2.23 wks	9/24/15 9::	10/7/15 8:(	5
7		1.3.4	E	Hydraulic design	2.23 wks	9/24/15 9::	10/7/15 8:(	5
8		1.3.5	F	Automatic computer design	1.12 wks	9/24/15 9::	9/30/15 2::	5
9		**1.4**		**Constructing prototype**	**108.74 day**	**9/30/15 2::**	**1/4/16 10::**	
10		1.4.1	G	Mechanical construction	10.7 wks	10/7/15 8:(	12/10/15 3	6
11		1.4.2	H	Assembling a hydraulic system	4 days	12/10/15 3	12/16/15 1	7,10
12		1.4.3	I	Assembling sensors and PLC	3 days	12/10/15 3	12/15/15 1	8,10
13		1.4.4	J	Wiring (electrical wiring, sensors, field network...)	4 days	12/16/15 1	12/21/15 4	11,12
14		1.4.5	K	Developing and coding PLC application	4.25 wks	9/30/15 2::	10/28/15 1	8
15		1.4.6	L	Developing and coding computer application	5.29 wks	9/30/15 2::	11/4/15 8::	8
16		1.4.7	M	Linking network to information system	1.47 days	12/21/15 4	1/4/16 10::	13,15
17		1.4.8	N	Integration mechanics, hydraulics, automation	8.8 days	12/21/15 4	1/4/16 8:2:	12,13,14
18		**1.5**		**Tests and checks**	**128.34 day**	**9/24/15 9::**	**1/13/16 9::**	
19		1.5.1	O	Network test	2.25 days	1/4/16 10::	1/6/16 8:5(	16,17
20		1.5.2	P	Testing and checking prototype	1.27 wks	1/6/16 8:5(	1/13/16 9::	19,21
21		1.5.3	Q	Technical documentation	2.27 wks	9/24/15 9::	10/8/15 9::	5
22		**1.6**		**Marketing**	**10.4 days**	**1/13/16 9::**	**1/21/16 9::**	
23		1.6.1	R	Finalizing technical documentation	2.39 days	1/13/16 9::	1/15/16 10	20,21
24		1.6.2	S	Commercial documentation	1.13 wks	1/13/16 9::	1/20/16 9::	20,21
25		1.6.3	T	Presenting to client and approval	1.27 days	1/20/16 9::	1/21/16 9::	23,24
26		1.7		End of the project	0 days	1/21/16 9::	1/21/16 9::	25

Figure 3.23. *The task table and its WBS number column*

In Figure 3.23, we can see the hierarchical coding that we have defined. This is automatically applied in ascending order by level depending on the importance of the task (recap or not).

3.2.12. *Generating dashboards and reports*

There is still the possibility of editing different dashboards in order to ensure that the project is monitored and presented.

To add to this, we can also generate reports to provide an overview of the use of resources, the cost of tasks, etc.

Below, you will find some examples of possible dashboards and reports.

Microsoft Project has a number of possibilities for creating different types of dashboards and graphs using raw data from the project or a pivot table of data that can be exported to a spreadsheet such as Microsoft Excel for further use.

3.2.12.1. *Tasks/work time dashboard*

This table is based on displaying task use. It is possible to open a task to view the time details depending on the resources, as Figure 3.24 shows with the task "Mechanical construction".

Task Name	Work	Duration	Start	Details	T	S	W	S	T
						Sep 21, '15		Oct 26, '15	
Project launch	0 hrs	0 days	1/15 8:0	Work					
Defining specifications	945.5 hrs	5.88 wks	1/15 8:0	Work					
Design	**,240.5 hrs**	**95.28 days**	**7/15 8:3**	Work	719.25h	332.13h	179.13h		
Basic design	,810.5 hrs	6.05 wks	7/15 8:3	Work					
Detailed design	,016.5 hrs	5.28 wks	1/15 5:2	Work	719.25h	97.75h			
Mechanical design	150.25 hrs	2.23 wks	1/15 9:2	Work		67.25h	83h		
Hydraulic design	150.25 hrs	2.23 wks	1/15 9:2	Work		67.25h	83h		
Automatic computer design	113 hrs	1.12 wks	1/15 9:2	Work		99.88h	13.13h		
Constructing prototype	**,092.4 hrs**	**108.74 days**	**0/15 2:2**	Work			784.13h	935.5h	703h
Mechanical construction	2,188.5 hrs	10.7 wks	10/7/15	Work			408.63h	643.5h	694.63h
Project manager	*262.5 hrs*		*7/15 8:0*	Work			62.88h	99h	100.63h
Design office	*262.5 hrs*		*7/15 8:0*	Work			55.88h	88h	96h
Mechanical engineer	*291.5 hrs*		*7/15 8:0*	Work			59.38h	93.5h	102h
Fitter 2	*321 hrs*		*7/15 8:0*	Work			59.38h	93.5h	102h
Technician 1	*350.5 hrs*		*7/15 8:0*	Work			59.38h	93.5h	102h
Technician 2	*372.25 hrs*		*7/15 8:0*	Work			59.38h	93.5h	102h
Logistics	*328.25 hrs*		*7/15 8:0*	Work			52.38h	82.5h	90h
Assembling a hydraulic system	120 hrs	4 days	0/15 3:5	Work					
Assembling sensors and PLC	135 hrs	3 days	0/15 3:5	Work					
Wiring (electrical wiring, sensors, fi	150 hrs	4 days	15 10:5	Work					
Developing and coding PLC applicati	300.88 hrs	4.25 wks	0/15 2:2	Work			187.75h	113.13h	
Developing and coding computer ap	375 hrs	5.29 wks	0/15 2:2	Work			187.75h	178.88h	8.38h
Linking network to information syst	26.03 hrs	1.47 days	1/15 4:2	Work					
Integration mechanics, hydraulics, a	797 hrs	8.8 days	1/15 4:2	Work					
Tests and checks	**780.88 hrs**	**128.34 days**	**1/15 9:2**	Work		93.88h	151.5h		
Network test	75 hrs	2.25 days	16 10:5	Work					
Testing and checking prototype	460.5 hrs	1.27 wks	1/16 8:5	Work					
Technical documentation	245.38 hrs	2.27 wks	1/15 9:2	Work		93.88h	151.5h		
Marketing	**199.5 hrs**	**10.4 days**	**1/16 9:5**	Work					
Finalizing technical documentation	30.93 hrs	2.39 days	1/16 9:5	Work					
Commercial documentation	112.5 hrs	1.13 wks	1/16 9:5	Work					
Presenting to client and approval	56.08 hrs	1.27 days	0/16 9:5	Work					
End of the project	0 hrs	0 days	1/16 9:5	Work					

Figure 3.24. *Table displaying work time for each of the tasks*

3.2.12.2. *Resources/work time dashboard*

This follows the same principle as the previous table, but is guided by resources, with the possibility of seeing details for each of the tasks. See the resource "Mechanical engineer" from Figure 3.25.

Resource Name	Work	Details	Aug 17, '15 M	W	F	Sep 21, '15 S	T	Oct 26, '15 T	S
Unassigned	0 hrs	Work							
Project manager	815 hrs	Work	24.5h	81.63h	65.88h		89.88h	108h	64
Assistant mechanic for project	439.88 hrs	Work	63h	26.38h		70.63h	4.38h		
Assistant hydraulic for project	439.88 hrs	Work	63h	26.38h		70.63h	4.38h		
Computer automation assistant for project	337.5 hrs	Work	24.5h			37.5h			
Design office	525 hrs	Work	38.5h	72.13h	40.38h		79.88h	96h	
Mechanical engineer	756.75 hrs	Work	48h	76.63h	35.88h	66.63h	93.5h	102h	7
Basic design	*166.5 hrs*	Work	48h						
Detailed design	*112.5 hrs*	Work		76.63h	35.88h				
Mechanical design	*75.25 hrs*	Work				66.63h	8.63h		
Mechanical construction	*291.5 hrs*	Work					84.88h	102h	7
Integration mechanics, hydraulics, automation	*45 hrs*	Work							
Network test	*15 hrs*	Work							
Testing and checking prototype	*43.5 hrs*	Work							
Presenting to client and approval	*7.5 hrs*	Work							
Electrical engineer	637.5 hrs	Work	59.5h	81.63h	42.38h	66.13h	93.5h	27.88h	
Hydraulic engineer	531.28 hrs	Work	59.5h	98.13h	42.88h	66.63h	8.63h		
Computer engineer	680.93 hrs	Work	59.5h	101.5h	42.88h	66.63h	93.5h	65.38h	
Developer 1	191.38 hrs	Work				27.13h	88h	35.75h	
Developer 2	228 hrs	Work				27.13h	88h	72.38h	
Fitter 1	137 hrs	Work							
Fitter 2	412 hrs	Work					84.88h	102h	7
Fitter 3	63.5 hrs	Work							
Fitter 4	52.5 hrs	Work							
Fitter 5	52.5 hrs	Work							
Technician 1	500 hrs	Work					84.88h	102h	7
Technician 2	563.38 hrs	Work				66.63h	93.5h	102h	7
Technician 3	73.5 hrs	Work							
Technician 4	130.13 hrs	Work				66.63h	18.5h		
Secretary-editor	539.43 hrs	Work	52.5h	89.5h	51.88h	58.63h	16.5h		
Marketing	37.5 hrs	Work							
Commercial sector	240.5 hrs	Work							
Logistics	548.75 hrs	Work		67.63h	75h	23.88h	74.88h	90h	6
Quality control	150.53 hrs	Work							
Team leader 1	91 hrs	Work							
Team leader 2	83.5 hrs	Work							

Figure 3.25. *Table showing the work time for each of the resources*

3.2.12.3. *Visual and chart reports*

Using the report generator allows us to create the chart in Figure 3.26, comparing the work time for each of the resources to their availability.

To get this result, we had to extract the data in order to create a histogram, made by crossing multiple data (pivot table).

When the chart is formatted, it is possible to save it in Microsoft Excel as an HTML page (in order to use it on a website) or even as an Open Document Spreadsheet (ODS), a document format for spreadsheets).

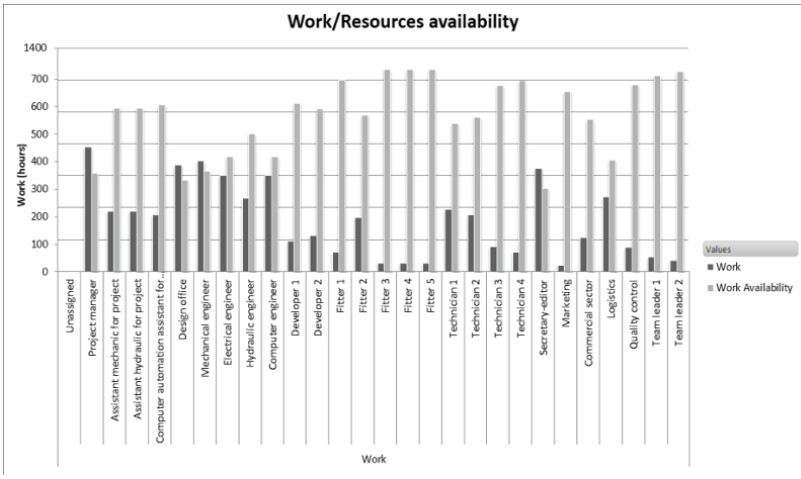
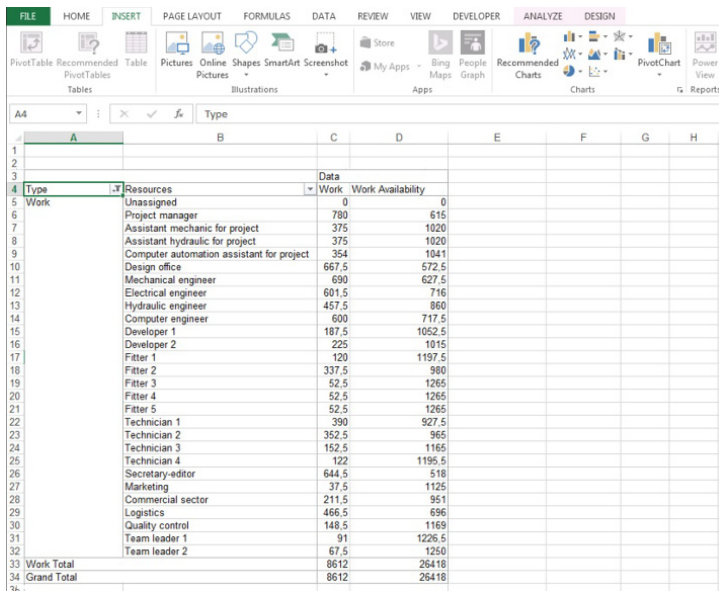


Figure 3.26. *A pivot table generated by the "Visual reports" tool in Microsoft Project 2013*

Figure 3.27 shows the Microsoft Excel spreadsheet that allowed us to create the previous chart.



	A	B	C	D	E	F	G	H
1								
2								
3			Data					
4	Type	Resources	Work	Work Availability				
5	Work	Unassigned	0	0				
6		Project manager	780	615				
7		Assistant mechanic for project	375	1020				
8		Assistant hydraulic for project	375	1020				
9		Computer automation assistant for project	354	1041				
10		Design office	667,5	572,5				
11		Mechanical engineer	690	627,5				
12		Electrical engineer	601,5	716				
13		Hydraulic engineer	457,5	860				
14		Computer engineer	600	717,5				
15		Developer 1	187,5	1052,5				
16		Developer 2	225	1015				
17		Fitter 1	120	1197,5				
18		Fitter 2	337,5	980				
19		Fitter 3	52,5	1265				
20		Fitter 4	52,5	1265				
21		Fitter 5	52,5	1265				
22		Technician 1	390	927,5				
23		Technician 2	352,5	965				
24		Technician 3	152,5	1165				
25		Technician 4	122	1195,5				
26		Secretary-editor	644,5	518				
27		Marketing	37,5	1125				
28		Commercial sector	211,5	951				
29		Logistics	466,5	696				
30		Quality control	148,5	1169				
31		Team leader 1	91	1226,5				
32		Team leader 2	67,5	1250				
33	Work Total		8612	26418				
34	Grand Total		8612	26418				

Figure 3.27. *The Microsoft Excel spreadsheet, created in Microsoft Project, that allowed us to generate the chart in Figure 3.26*

3.3. Project monitoring

Once the project is underway, the project manager will be responsible for monitoring it. Each change made, whether this is to tasks or to resources, is automatically registered and the scheduling is entirely recalculated (if the automatic scheduling method is activated for the relevant task(s)).

As time passes and the project progresses through the calendar, a task can be selected and given a completion percentage using the burndown tools available in the ribbon under the TASK tab in the SCHEDULE group.

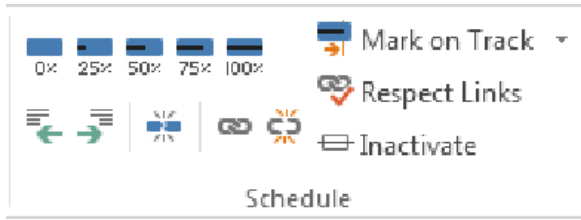


Figure 3.28. *The burndown and scheduling tools available in the ribbon under the TASK tab*

The project can also be managed with an appropriate burndown, by specifying a status date (PROJECT tab, STATUS DATE tool in the ribbon) then by updating the project using the UPDATE PROJECT tool in the STATUS group. In this instance, Microsoft Project considers all the tasks as having been completed up to this point (by default).

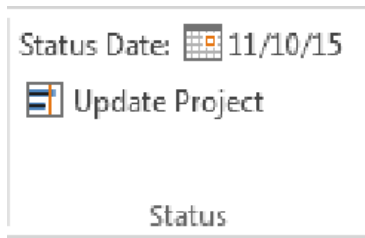


Figure 3.29. *The tools for managing the status date under the PROJECT tab*

The burndown in the task completion is visible on the Gantt chart. The task bars have a bold line down the middle indicating burndown.

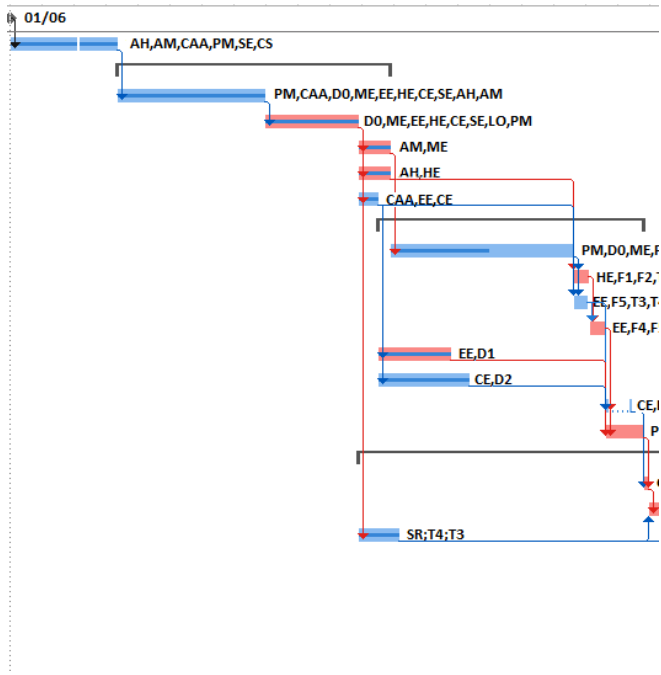


Figure 3.30. *Here we can see the burndown (bold horizontal line in the middle of the task bars)*

To conclude, it can be observed that the bars in the Gantt chart, which correspond to each of the tasks, are interactive, and can be adjusted to move the task along the timeline (cursor in the shape of a crossed arrow), stretched to extend the duration of the task (cursor in the shape of an arrow pointing right will appear at the end of the bar), or given a burndown (cursor in the shape of a % sign and a triangle will appear at the start of the bar). Naturally, each modification is carried out instantaneously and the project is recalculated as a result, if the automatic scheduling mode has been activated for the relevant task (Figure 3.31).

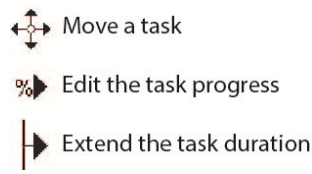


Figure 3.31. *The functions of the different shapes of cursor that appear when hovering over a bar representing a task in a Gantt chart*

3.4. Conclusion

There are various other observations we could make on the functionalities available with Microsoft Project. However, I think that the elements presented here show the main possibilities available with the program.

I have intentionally left out the question of multi-project management, a form of management using sub-projects and resource sharing. To develop this further, to learn about these possibilities and to discover more, I would advise you to consult the Bibliography and the list of internet links included at the end of this book.

4

Road Traffic Simulation

4.1. Before we start

Unlike the previous chapters, here I will introduce several pieces of free simulation software before finishing with an example developed using AnyLogic.

Why was this choice made?

It was made in accordance with the wealth of options available to the editors. There is a vast range of software available, covering one or several types of models, and these are often quite complex and difficult to master. They require an excellent knowledge of the theory of road networks, infrastructures, signaling, land topography and various other concepts in order to create a model that will satisfy the design brief while staying in keeping with the right approach.

In the space of just one chapter, it would be difficult to explain all of these elements to the reader and to apply them within a chosen application.

I would advise you to consult section 4.3 from Chapter 10 of Volume 1 of this work to obtain an overview of the possibilities available with the main applications available on the market and to download and use the trial versions to allow you to form your own opinions.

We will deal with several examples and in these I will focus on certain functions that will then enable the reader to discover key aspects of road traffic management.

Modeling and Simulation of Logistics Flows 2: Dashboards, Traffic Planning and Management,
First Edition. Jean-Michel Réveillac.

For each example, I will provide a brief overview of the application. I will also provide links to websites where you will be able to download these programs in the internet links section of the bibliography at the end of this work.

4.2. Ring road

This program is available online at[1]: www.traffic-simulation.de. The software is the creation of Martin Treiber, a specialist in traffic modeling and the author of several works that can be found in the bibliography.

This application provides an excellent approach to congestion problems and their consequences: slowing down, blockages, the build-up of vehicles.

Slight changes to any of the parameters will have a significant impact on traffic flow, in the short or the long term.

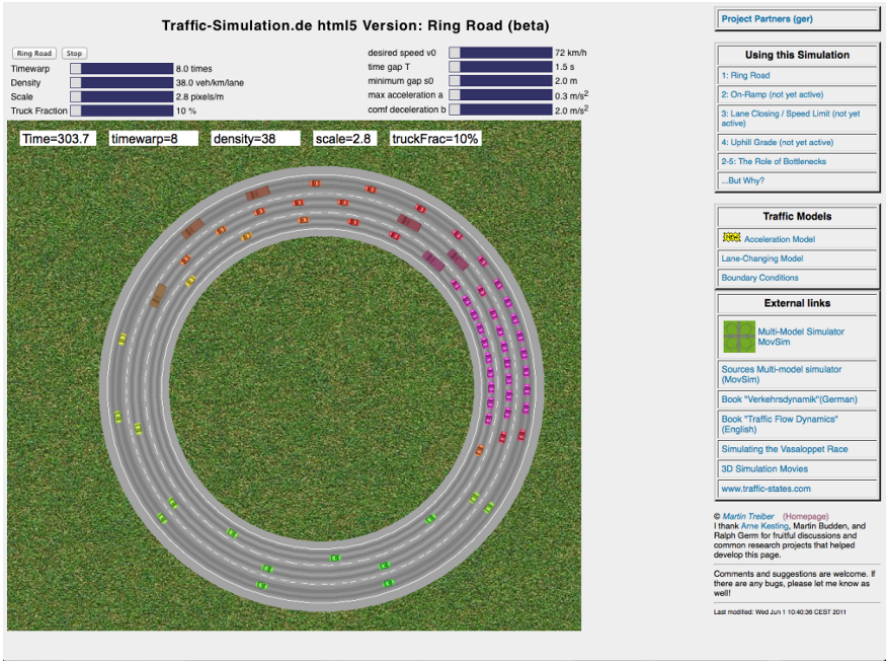


Figure 4.1. *The website of Martin Treiber's simulator "Ring road"*

1 This link was active at the time of writing. Should any problems arise, use your preferred search engine.

The role of each of the sliders positioned above the simulation ring is given below:

– *Timewarp*: multiplier timescale (from 0.1 to 20 times);

– *Density*: density, number of vehicles per kilometer and per road;

– *Scale*: scale of the window of the simulator (from 0.6 to 5 pixels/meter);

– *Truck fraction*: percentage of trucks relative to other vehicles (from 0 to 50%);

– *Desired speed v0*: vehicle speed (from 18 to 144 km/h);

– *Time gap T*: time gap between vehicles (from 0.6 to 3 seconds);

– *Minimum gap s0*: space between vehicles (from 0.5 to 5 meters);

– *Max acceleration*: maximal acceleration of vehicles (from 0.3 to 3 m/s^2);

– *Comf deceleration*: comfortable deceleration of vehicles, i.e. without emergency braking, in normal conditions (from 0.5 to 5 m/s^2).

While running the application, the user can refer to or consult the links available at the right of the display window for more information.

Three traffic models are also presented:

– the *acceleration model* based on the Intelligent Driver Model (IDM) developed by Treiber, Hennecke and Helbing in 2000;

– the *lane-changing model* based on the Minimizing Overall Braking Induced by Lane (MOBIL) changes model by Kesting, Treiber and Helbing;

– *Boundary conditions*, which is based on the conditions at the limits of the traffic area chosen for the study for periodic cases (circular or ring circuit) or road sections that are not required to be periodic.

At the time of writing, some features of the application are not yet active, including road closure and speed limits.

4.2.1. *A simulation example*

Let's start with a simulation using the parameters in Figure 4.2.

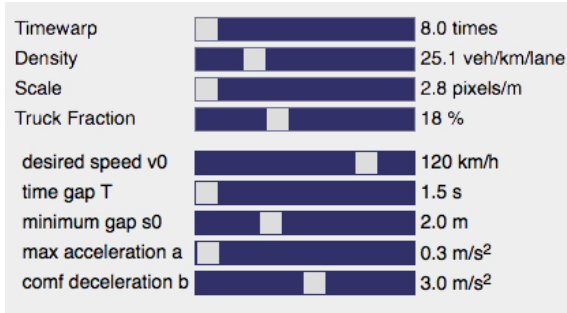


Figure 4.2. *The parameters for simulation no. 1*

With these sliders we can observe that the traffic remains fluid although reductions in speed can occur.

If we are to increase the vehicle density from 25 to 50, a congestion appears, which could be considered a blockage.

By reducing speed to 60 km/h and the density to 35 veh/km/lane with a gap between vehicles of 1.0 m, traffic will become fluid again and will remain within the blockage limits.

We can see the priority influence of density on traffic flow. Other variables, such as the speed or the distance between vehicles are less significant, although they still contribute to the phenomenon.

4.3. RoadTrafficSimulator

This program was developed by Artem Vokhin in 2014 and is available to download at[2]: *github.com/volkhin/RoadTrafficSimulator*. It is based on the traffic models IDM and MOBIL mentioned in the previous section. To use it you will require a web browser such as Mozilla Firefox, Microsoft Internet Explorer, Safari, Google Chrome, etc. It was developed in CoffeeScript[3] and HTML5[4].

2 This line was active at the time of writing. Should any problems arise, use your preferred search engine.
3 CoffeeScript is a programming language created in 2009 by J. Ashkenas that compiles into Javascript.
4 HTML 5.0 is the most recent major version of HyperText Markup Language (HTML), a language for formatting data, that was devised for creating websites. It dates back to 1991 and is based on Standard Generalized Markup Language (SGML).

You can design your own network or even manage it automatically and view traffic flow within a model incorporating crossings with traffic lights.

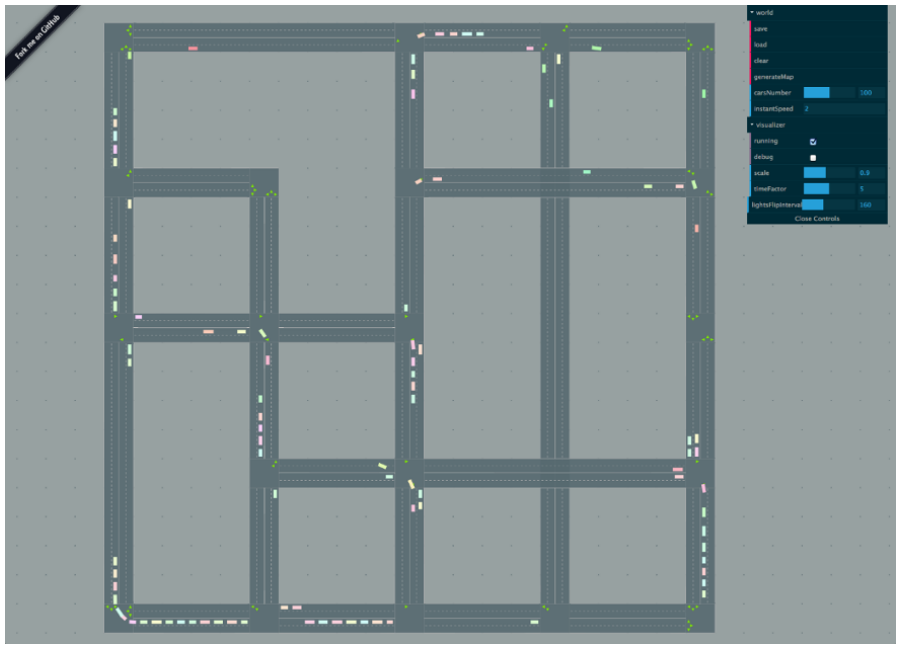


Figure 4.3. *The application RoadTrafficSimulator in use with its control interface at the top right*

Several parameters can be adjusted using the control interface:

– *World*: opens the drop-down menu containing the options *save, load, clear and generateMap*;

– *Save*: save the current model;

– *Load*: load a saved model;

– *Clear*: delete the model;

– *generateMap*: automatically generates a random model;

– *carsNumber*: specifies the number of vehicles (from 0 to 200);

– *instantSpeed*: snapshot of average speed for all vehicles in the model;

– visualizer: opens the drop-down menu containing the *running* and *debug* options;

– *running*: launches (ticked) or stops (unticked) the simulation;

– *debug*: displays the trajectories of vehicles at intersections;

– *scale*: modifies the scale of the model (from 0.1 to 2);

– *timeFactor*: accelerates or slows down the simulation (from 0.1 to 20);

– *lightsFlipInterval*: modifies the rhythm of traffic lights (from 0 to 400);

– *Close Controls*: Minimizes and closes the control interface window;

– *Open Controls*: Opens the control interface window.

Using the scroll wheel on the mouse allows you to zoom in or out on the model (double-use with the **SCALE** adjustment of the interface). Right-clicking followed by a drag and drop will move the model in the window.

A grid made up of points will formalize a square grid that will still be found at the bottom of the window of the model.

4.3.1. *Constructing a model*

Once you have downloaded and decompressed RoadTrafficSimulator, open the RoadTrafficSimulator folder and double-click on the index.html folder.

A model should appear, generated by default. Before you begin you can adjust the sliders in order to familiarize yourself with the interface and to see the influence this has on the existing road network.

The vehicles are represented by small colored rectangles and each street will feature four lanes.

The traffic lights at each intersection are represented by small green triangles indicating the direction and the priority of traffic.

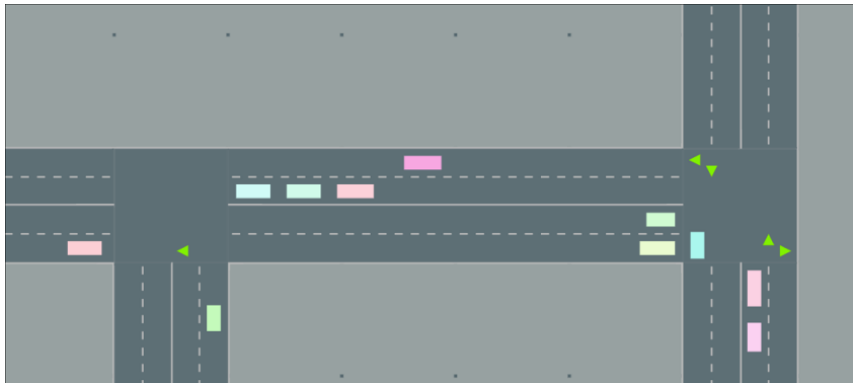


Figure 4.4. *Two intersections with the indicators (green triangles) representing the traffic lights. For a color version of this figure, see www.iste.co.uk/reveillac/modeling2.zip*

Strictly speaking, there are two stages to building a model:

– start by deleting the existing model. Click on **CLEAR** in the configuration interface (make sure that **RUNNING** is ticked, otherwise the deletion will not be taken into account);

– hold down the SHIFT key on your keyboard and click seven times on different areas in the window to create intersections for your future model (see Figure 4.5);

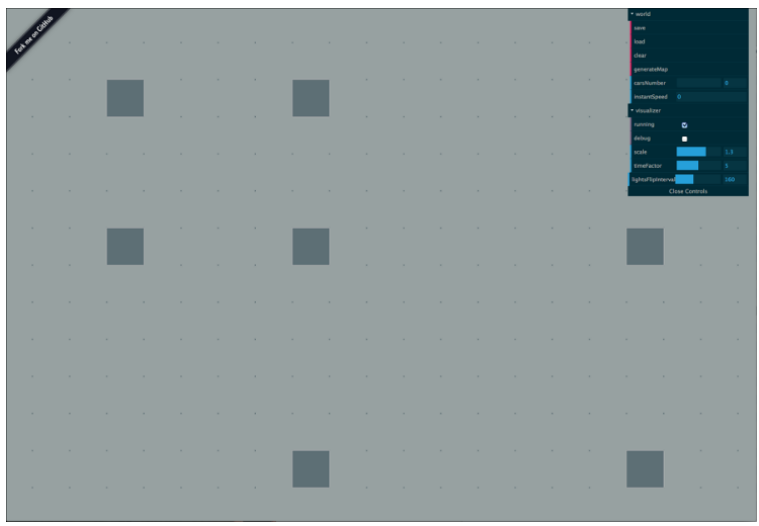


Figure 4.5. *The 7 intersections created for our model*

– click on the intersections that you have created, hold down the SHIFT key on your keyboard and, while maintaining a left-click, drag to connect to another intersection. A road with two lanes should appear;

– repeat the same steps in order to create each of the sections of the network from Figure 4.6;

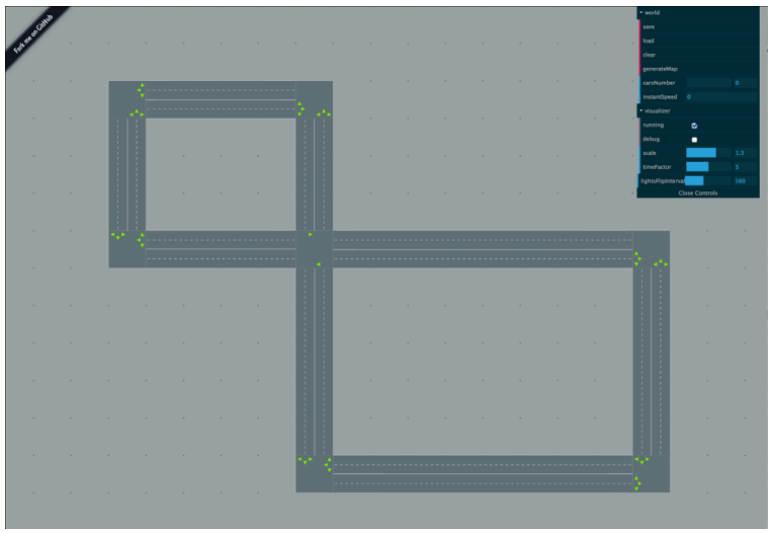


Figure 4.6. *Our network once the different intersections have been connected*

– click on **SAVE** in the interface in order to save your model. No dialog box will appear but the model will have been saved. The next time you launch the application, this is the model that will appear. Clicking **LOAD** will also bring up this model, which will become the default model.

4.3.2. *Activating the simulation from the model*

In the interface, specify a number of vehicles using the **CARSNUMBER** cursor.

Your simulator should start automatically if the **RUNNING** option is ticked.

By varying the number of vehicles and the rhythm of the traffic lights, **LIGHTSFLIPINTERVAL**, you will be able to see the queues of vehicles and the overall snapshot speed, **INSTANTSPEED**, for all vehicles present in your network.

The aim is to reach a high overall snapshot speed while avoiding congestion and blockages at intersections.

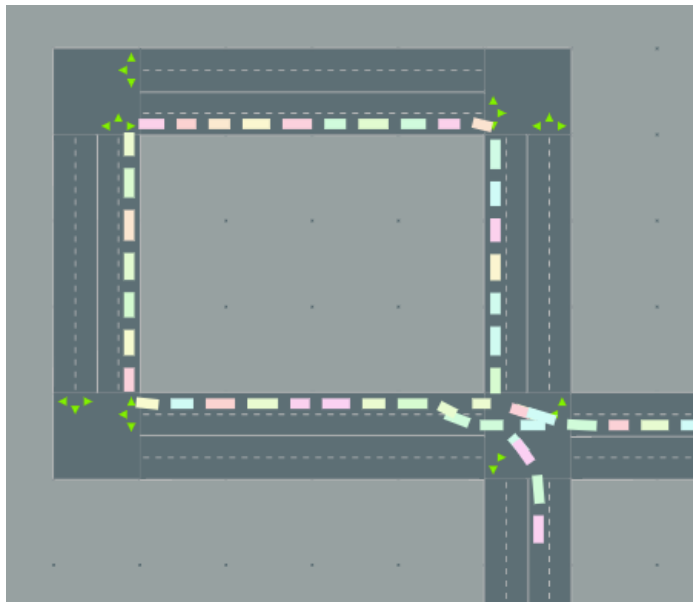


Figure 4.7. *Blockage and congestion of traffic lanes around an intersection (traffic jam)*

4.4. Intersection simulator

This application was developed in Java by Kresimir Kovacic and simulates junctions with the management of traffic lights. It is possible to modify various parameters and a graph will give a real-time display of the average waiting time in traffic routes.

This software is distributed under the Creative Commons license and is available to download at[5]: *sourceforge.net/projects/traffic-simulator/*.

A right-click on the "intersection_simulator.jar" folder will launch the program.

5 This link was active at the time of writing. Should any problems arise, use your preferred search engine.

COMMENT 4.1.– In order for this application to function properly on your machine, Java must be installed. If you don't have Java on your system, it is available to download for free at *www.java.com/en/*. If this address doesn't work, use a search engine and search for "Java".

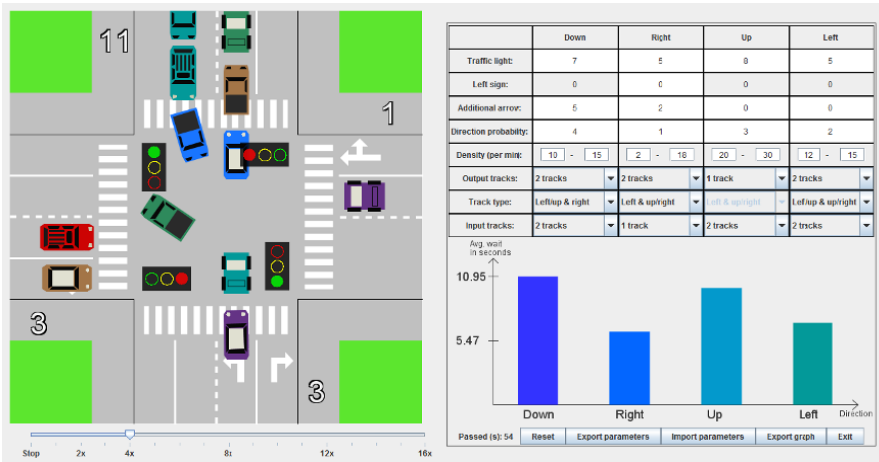


Figure 4.8. *The Intersection simulator program window*

The display window is divided into five main sections:

– the graphic simulation zone, on the left, that shows the junction at which we can view the circulation of vehicles and the different indicators;

– the parameter table, on the right, where we can specify the values of the different variables;

– the time management cursor, at the bottom left, that allows us to speed up, slow down or stop the simulation;

– the graph area, beneath the parameter table, that displays the lane management histogram;

– the set of interface commands beneath the histogram, which contains the number of cycles carried out by the simulation and the five buttons available to the user.

Let's now look in more detail at the different parameters in the table:

	Down	Right	Up	Left
Traffic light:	5	0	0	0
Left sign:	0	0	0	0
Additional arrow:	0	0	0	0
Direction probability:	1	1	1	1
Density (per min):	12 - 18	0 - 0	0 - 0	0 - 0
Output tracks:	2 tracks	2 tracks	2 tracks	2 tracks
Track type:	Left & up/right	Left & up/right	Left & up/right	Left & up/right
Input tracks:	2 tracks	2 tracks	2 tracks	2 tracks

Figure 4.9. *The parameter table*

– each of the four columns represents one of the directions at the intersection: **DOWN** (bottom), **RIGHT** (right), **UP** (top), **LEFT** (left);

– the first row, **TRAFFIC LIGHT**, is for the main light of the chosen direction. The value represents the rhythm at which the lights change;

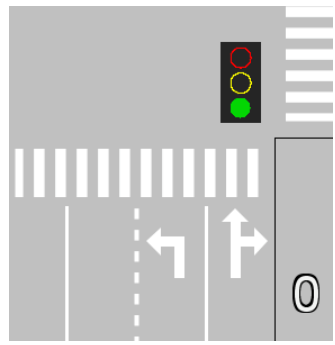


Figure 4.10. *The TRAFFIC LIGHT system for the bottom lane (Down)*

– the second row, **LEFT SIGN**, is for the additional light for the extra lane. Its value represents the rhythm at which the lights change;

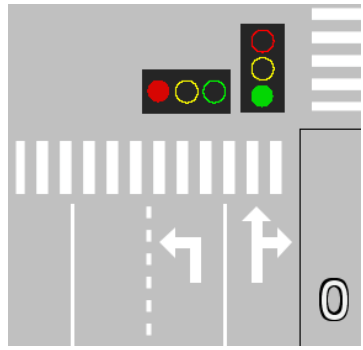


Figure 4.11. *The TRAFFIC LIGHT system and LEFT SIGN for the bottom lane (Down)*

– the **ADDITIONAL ARROW** row adds an arrow indicating direction when it is possible to turn. Its value represents how long it will remain activated;

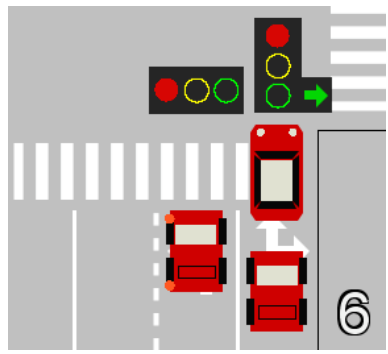


Figure 4.12. *The ADDITIONAL ARROW, shown to the right of the TRAFFIC LIGHT system*

– the **DIRECTION PROBABILITY** row governs the probability of how vehicles will be distributed across the different lanes;

– the **DENSITY (PER MIN)** row specifies the number of vehicles arriving per minute. An interval can be determined using a minimal value (on the left) and a maximal value (on the right);

– the **OUTPUT TRACKS** row specifies the number of exit lanes, 1 or 2, for each direction;

– the **TRACK TYPE** row specifies the three possible directions that vehicles can take. **LEFT & UP/RIGHT** to go left, or straight on and right together. **LEFT/UP & RIGHT** to go left and straight on together, or to go right. **LEFT/UP & UP/RIGHT** to go left and straight on together, or to go straight on and right together.

– the **INPUT TRACKS** row specifies the number of entry lanes, 1 or 2, for each direction.

COMMENT 4.2.– Please note that the **OUTPUT TRACKS** and **INPUT TRACKS** parameters have matching functions. As a result, certain combinations are logically impossible.

Beneath the table there is a histogram featuring a continuous display of the average waiting time in seconds for each direction.

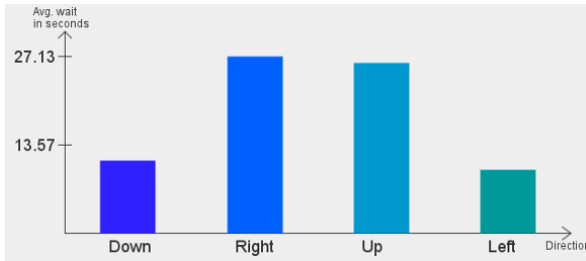


Figure 4.13. *The histogram showing average waiting times*

The number of vehicles waiting at each direction is shown on the right within the graphic simulation zone.

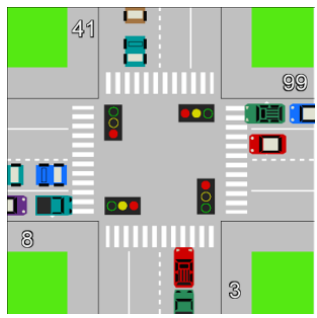


Figure 4.14. *Here we can see the number of vehicles waiting on the right-hand side for each direction. In this example, 3 at the bottom, 99 on the right, 41 at the top and 8 on the left*

We will now look at the function of each of the five buttons beneath the histogram:

– **RESET**: Resets the simulation and takes on the new parameters once they have been entered.

– **EXPORT PARAMETERS**: Saves the parameters entered into the table in TXT format, under your chosen name. A dialog box will open to confirm that your parameters have been saved.

– **IMPORT PARAMETERS**: Import the parameters from an exported file. A dialog box will open to confirm that the chosen folder has been imported.

– **EXPORT GRAPH**: Saves the graph from the simulation as a ZIP file containing a PNG image, *"Graph.png"*, representing the histogram and a file, *"Simulation_results.txt"*, in TXT format, that will contain the results of the simulation.

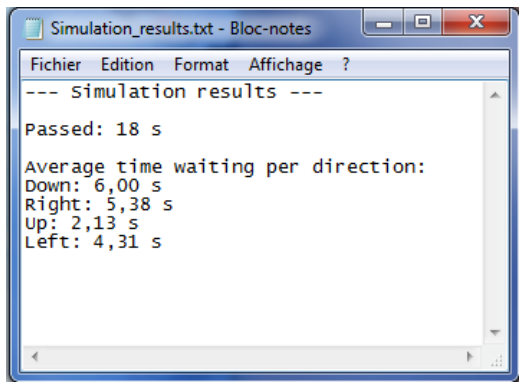


Figure 4.15. *An example of a TXT file extracted from an exported ZIP file, containing the results of the simulation*

– **EXIT**: exit the simulator.

Finally, moving the cursor over the graph simulation zone will allow you to vary the speed, from a complete stop **STOP** to up to 16 times real speed (once).

Once you have understood the use for these parameters and the different features of the application, it becomes very easy to simulate an intersection, including its different lanes and traffic lights.

4.5. Green Light District (GLD)

This program is a traffic simulator that allows you to create your own road network by incorporating different types of road with multiple traffic lanes and intersections controlled by traffic lights.

It was developed in Java at the Institute of Information and Computing Sciences at the University of Utrecht in the Netherlands. It is under license of the GNU General Public License version 2.0.

The concept behind the creation of GLD was to create a simulator based on the "intelligent" management of traffic lights.

Imagine that each car stopped at an intersection communicates its position in the queue and its final destination to a global system for triggering signals. The latter would then be able to select the optimal solution for reducing the waiting time for vehicles in the short and long term and would apply this for their entire journey, which would include one or several intersections controlled by traffic lights.

The overall control of the management of traffic lights is based on a distributed multi-agent system where mutual communication and cooperation ensures the best possible coordination.

GLD features several types of traffic light controllers, standard or training, in order to test and compare a range of solutions relating to the flow of vehicles in a network. Furthermore, it is possible to find out the type of vehicle – car, bus or bike – and use this information in accordance with statements defined by the experimenter.

Furthermore, the system is able to "learn", allowing it to become increasingly efficient over time.

It is available to download at[6]: *sourceforge.net/projects/stoplicht/*.

Although it does not present all of the features of the most recent version of the application, the documentation is available to download as a compressed file, "*gld_rel07_docs.zip*" at: *sourceforge.net/projects/stoplicht/files/OldFiles/gld_rel07_docs.zip/download*.

6 This link was active at the time of writing. Should any problems arise, use your preferred search engine.

The specifications of the software, version 0.9.2, are available to download at: *sourceforge.net/projects/stoplicht/files/OldFiles/gld_specs_0.9.2.zip/download.*

The version provided is not compiled, and you will need to install a Java compiler if you haven't already. You will then be able to compile sources.

Information on how to install the Java compiler can be found in Appendix 2 of this work.

4.5.1. *GLD compilation*

After downloading GLD, you should have a 570.6 Ko ZIP file named "*gld_rel131_source.zip"*. Version 1.3.1 is the most recent.

Decompress the file, open the folder "*gld_rel131_source*", and you should have a text file, "*very_quick_howto_build_and_run.txt*" and a folder "*gld*".

This version of GLD was developed using an older version of Java (pre 1.5), and it is necessary to specify this aspect during compilation, otherwise you will have errors caused by a variable known as "*enum*", unless you are using an older version of Java.

Open the folder *"gld_rel131_source",* then enter the command:

`javac -source 1.4 gld/*.java` and confirm by pressing ENTER.

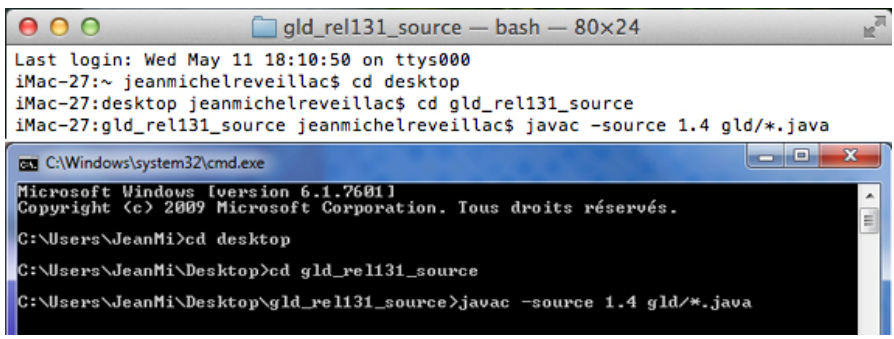


Figure 4.16. *The command for launching the compilation in Apple OSX (at the top) and in Microsoft Windows (at the bottom)*

You should obtain a result similar to the one in Figure 4.17.

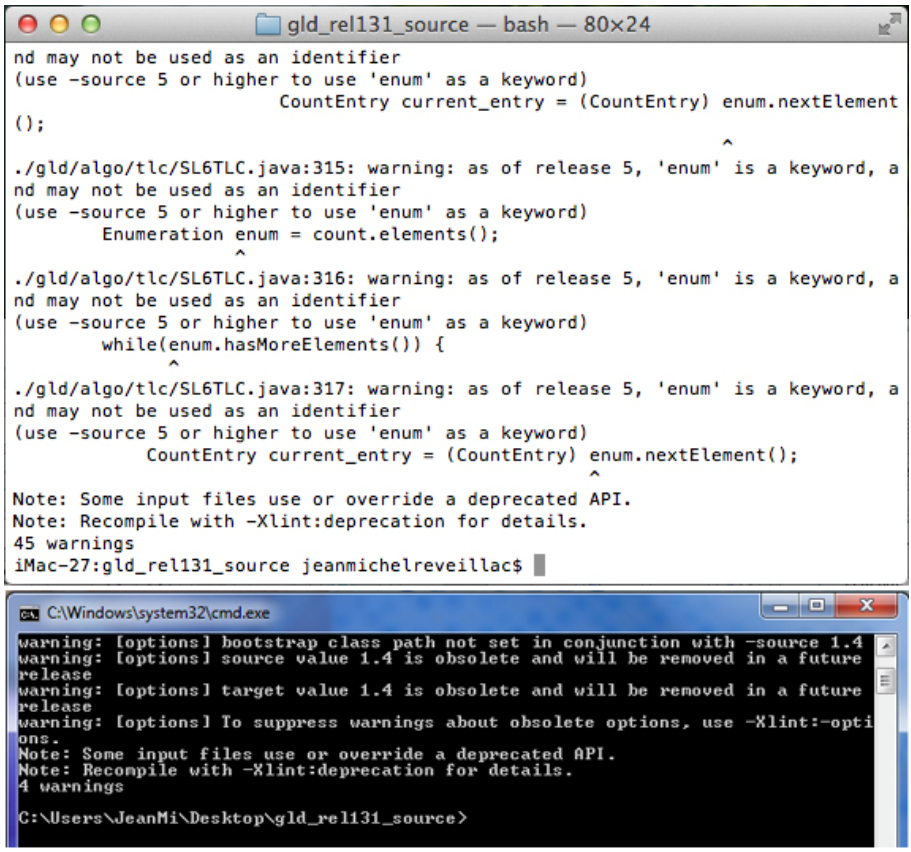


Figure 4.17. *Result after compilation in Apple OSX (at the top) and in Microsoft Windows (at the bottom)*

4.5.2. *Launching the GLD*

GLD is made up of two main applications: the editor “GLDEdit” and the simulator “GLDSim”.

Using the editor, it is possible to build your network by determining the lanes and intersections and then confirming your model.

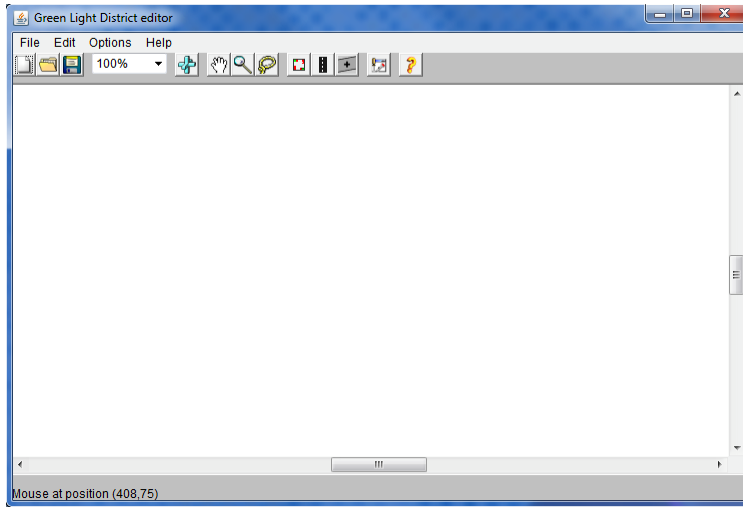


Figure 4.18. *The Green Light District editor*

This can be launched using the command "`java gld.GLDEdit`" on your command prompt.

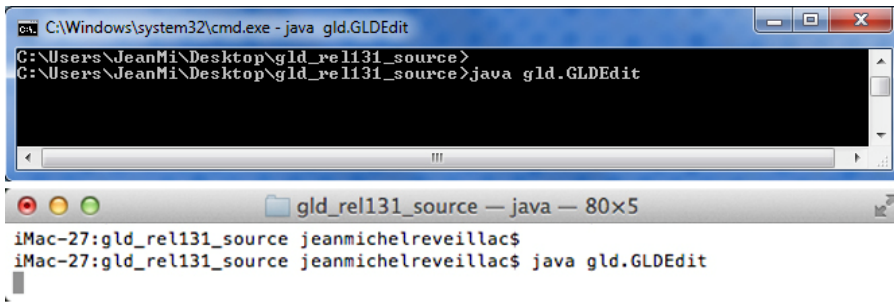


Figure 4.19. *The editor launch file, in Microsoft Windows using the command prompt (at the top) and in Apple OSX using Terminal (at the bottom)*

The simulator will, among other actions, open the model developed with the editor, position the vehicles in your network, assist you with the animation of the simulation, determine statistics and provide you with different options for managing traffic lights.

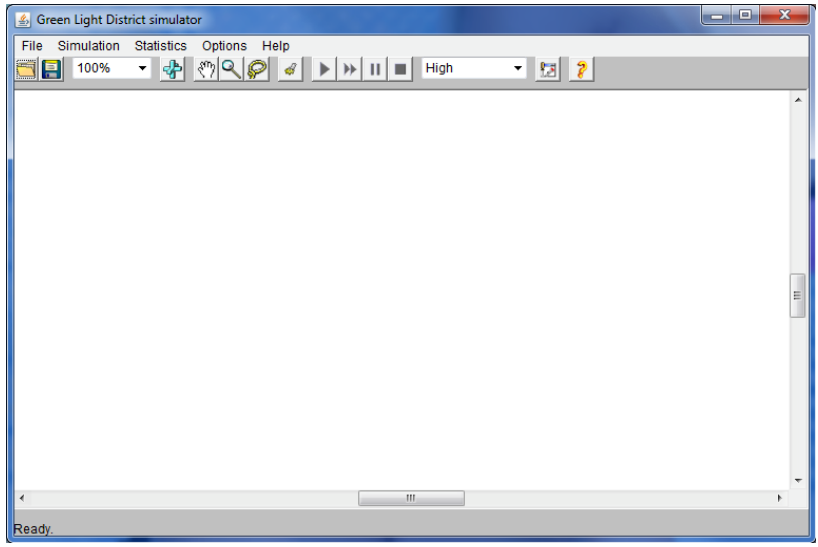


Figure 4.20. *The "GLDSim" simulator in Green Light District*

This can be launched using the command: `"java gld.GLDsim"` on your command prompt.

Figure 4.21. *The command for launching the simulator, in Microsoft Word using the command prompt (at the top) and in Apple OSX using Terminal (at the bottom)*

4.5.3. *The editor toolbar*

The GLD editor features a main toolbar with the following functions (Figure 4.22):

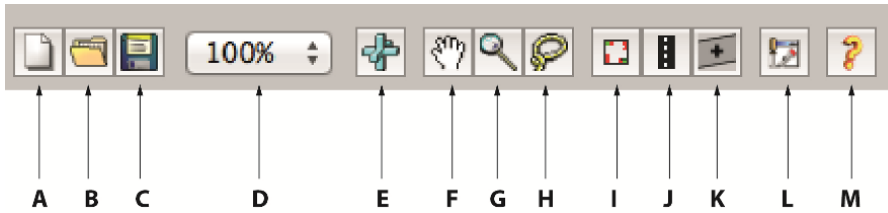


Figure 4.22. *The GLD editor toolbar*

– A: Create a new model, **WIDTH** and **HEIGHT**;

– B: Open an existing model. GLD files are "*.infra*" type;

– C: Save a model. The extension should be *".infra"* type;

– D: Model scale from 25 to 250 %;

– E: Centre the model in the window;

– F: Move the model in the window;

– G: Zoom in on the model;

– H: Select an item;

– I: Create an intersection. In this instance a drop-down menu will appear at the right of the toolbar, enabling you to select the type of intersection (*Edge node; Traffic lights; No signs; Net-tunnel*;

– J: Create a road linking two nodes;

– K: Add a lane to an existing link;

– L: Open the dialog box for the properties of the selected item;

– M: Help.

COMMENT 4.3.–

– In order for help to function, you will need to move the "docs" folder, which contains the ".html" files for the previously downloaded documentation into the "gld" folder (see section 4.5).

– To access the specifications from help, you will need to create a file "specs" in the "docs" folder and move the content from the "gld_specs_0.9.2" inside it (see section 4.5).

As with the editor, the simulator also has its own toolbar.

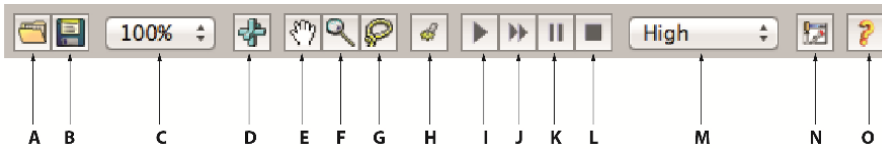


Figure 4.23. *The GLD simulator toolbar*

– A: Open an existing model. GLD files are *".infra"* type;

– B: Save a simulation. The extension should be *".sim"* type;

– C: Model scale from 25 to 250%;

– D: Centre the model in the window;

– E: Move the model in the window;

– F: Zoom in on the model;

– G: Select an item;

– H: Open the drop-down menu for selecting vehicle type: **CAR**, **BUS** or **BICYCLE**;

– I: **STEP** – Move the simulation one step forward;

– J: **RUN** – Launch the simulation;

– K: **PAUSE** – Pause the simulation;

– L: **STOP** – Stop the simulation;

– M: Choose the simulation speed : **LOW**, **MEDIUM**, **HIGH**, **MAXIMUM**;

– N: Open the dialog box for the properties of the selected item;

– O: Help.

4.5.4. *An example using GLD*

We will now create a simple model using GLD. Open *"GLDEdit"*.

The network that we will set up is the one shown in Figure 4.24.

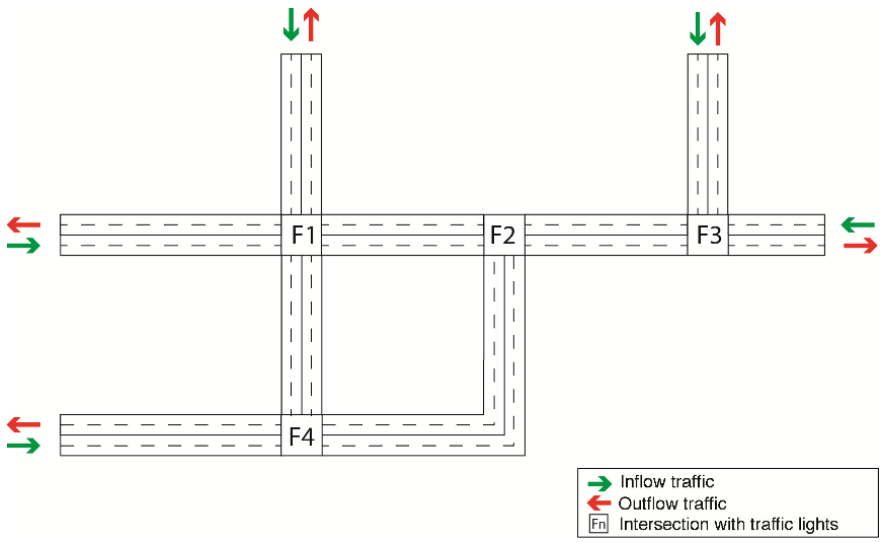


Figure 4.24. *The road network for our example, featuring 4 intersections, F1 to F4. For a color version of this figure, see www.iste.co.uk/reveillac/modeling2.zip*

It includes four intersections, F1, F2, F3 and F4, which are all controlled by traffic lights. Every road has five lanes and there are five entries and exits for vehicles. By default, the lanes will feature every type of vehicle.

4.5.4.1. *Creating a model*

COMMENT 4.4.– The capital letters between brackets in the text describing how to create a model refer to Figure 4.22.

This will occur as follows:

– in the GLD editor, in order to display the grid and to correctly position the different items of the network, open the **OPTIONS** menu and select **TOGGLE GRID**;

– click on the icon for creating intersections (I), select the type *"Traffic lights"* and position the four nodes (squares with black lines) F1, F2, F3 and F4;

– if there is an error it is possible to delete an element by right-clicking on the latter and selecting **DELETE**;

– the nodes will be numbered automatically, starting from 0, during creation;

– continue by placing five *"Edge node"* type intersections (squares with blue lines). These nodes border the model that generate and receive the flow of vehicles;

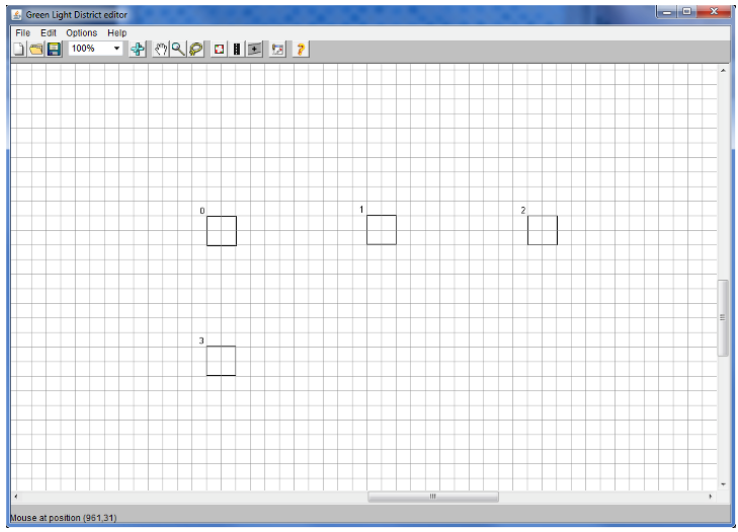


Figure 4.25. *The four "Traffic lights" type intersections in GLDEdit*

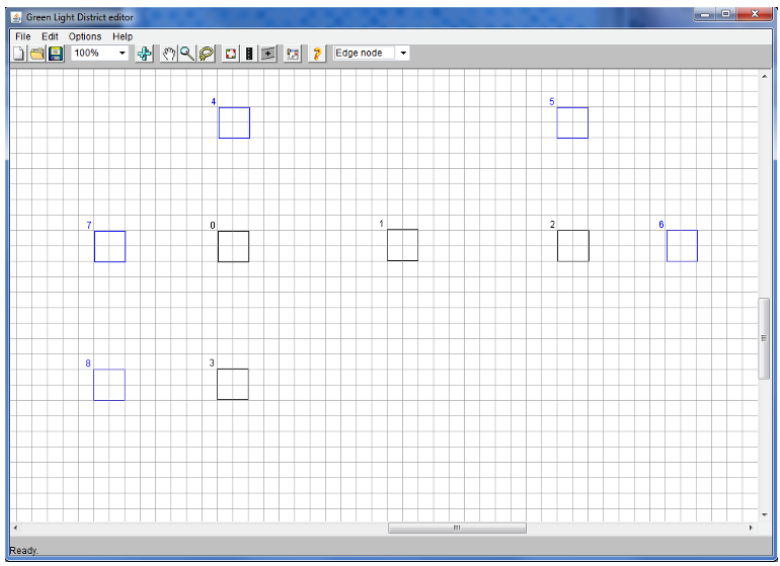


Figure 4.26. *The five "Edge node" type intersections" added to four "Traffic lights" blocks*

– next, select the type *"No signs"* and position a change of direction that will link F2 to F4;

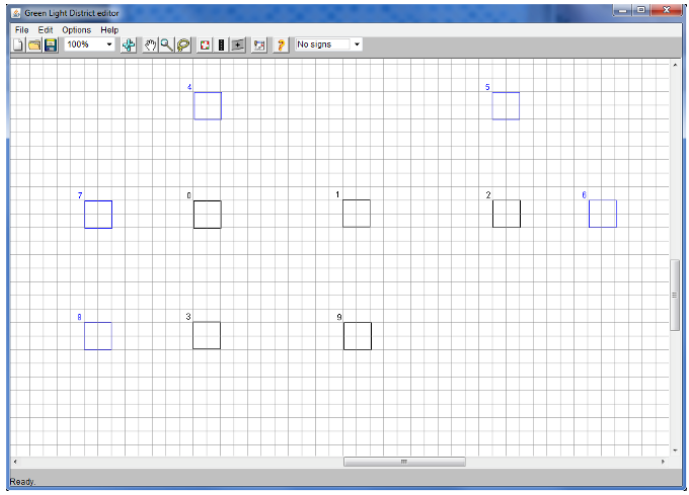


Figure 4.27. *Each intersection block*

– in the toolbar, select the tool for creating a route between two nodes (J) and create the different junctions;

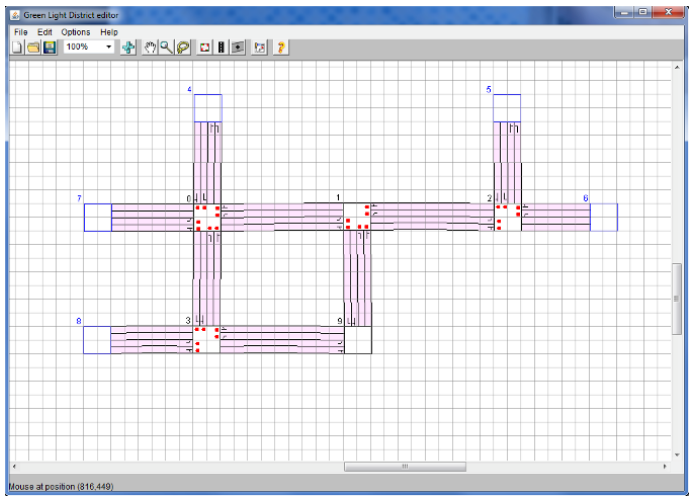


Figure 4.28. *The model showing road junctions (in pink). The junctions show the traffic lights set up by default*

– in the **OPTIONS** menu, select **VALIDATE** and confirm that the model is correct. The **GENERAL CONFIGURATION** window will be displayed.

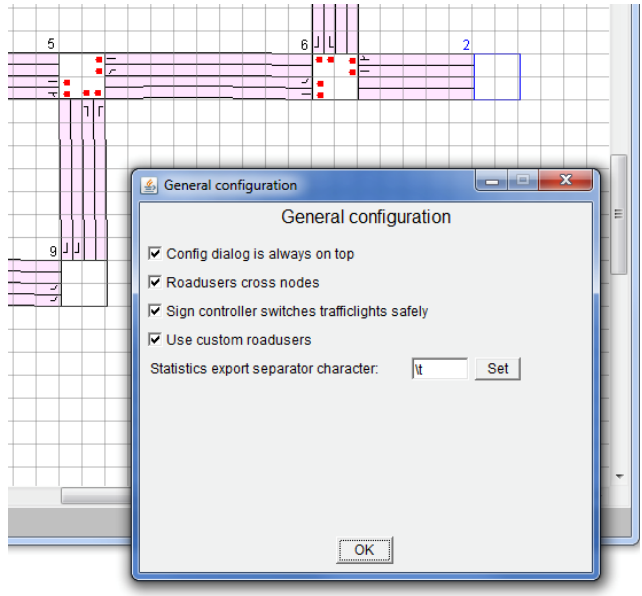


Figure 4.29. *The GENERAL CONFIGURATION window displayed when confirming your model*

If this is not the case, an **ERROR** dialog box will open to inform you of the errors and to allow you to correct them.

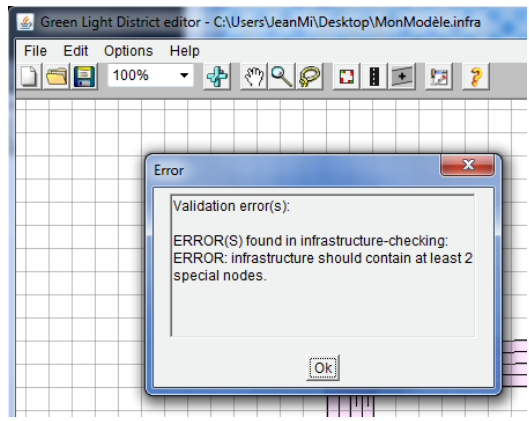


Figure 4.30. *An example of a potential error during confirmation*

– to save your model, open **FILE**, then select **SAVE AS…**

– select a destination folder and enter a name using the extension *".infra"*, then click on the **SAVE** button.

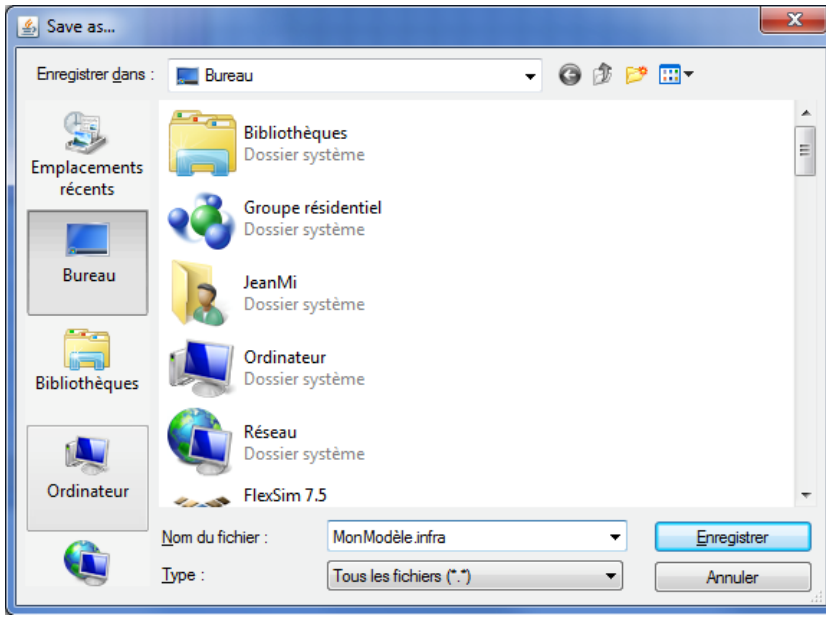


Figure 4.31. *Saving a model (in Microsoft Windows), here "MyModel.infra" in the Office folder*

Now that we have created our model, we are now able to use it.

4.5.4.2. *Traffic simulation*

Open *"GLDSim"* and open the model that you have previously created by selecting **FILE** followed by **OPEN**. This should appear within the main window of the simulator. If this is not the case, click on the center the model in the window icon (D) on the toolbar.

COMMENT 4.5.– The capital letters, in brackets, refer to Figure 4.23.

Lastly, zoom in for a more detailed view of the network.

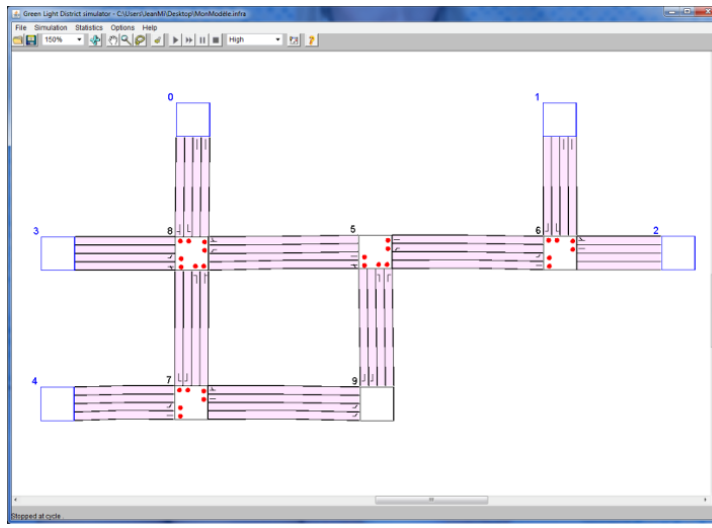


Figure 4.32. *The model centered in the "GLDSim" window and enlarged by 150%*

To start a simulation using the default settings, click on the icon for launching a simulation (J) in the toolbar.

It is possible to adjust the speed of the simulation by changing it via the drop-down menu (M) from **LOW** to **MAXIMUM**.

The simulation can be stopped by clicking on the **PAUSE** icon (K) and restarted by clicking on the **RUN** icon (J). To completely stop the simulation, use the **STOP** icon (L), which will remove all vehicles.

You can advance step by step using the **STEP** icon (I).

The number of cycles for the simulation will be displayed at the bottom left of the window.

The small red squares represent bicycles and the large green rectangles represent buses. The other grey, black, blue, white and green rectangles represent other vehicles.

The small green and red circles represent traffic lights.

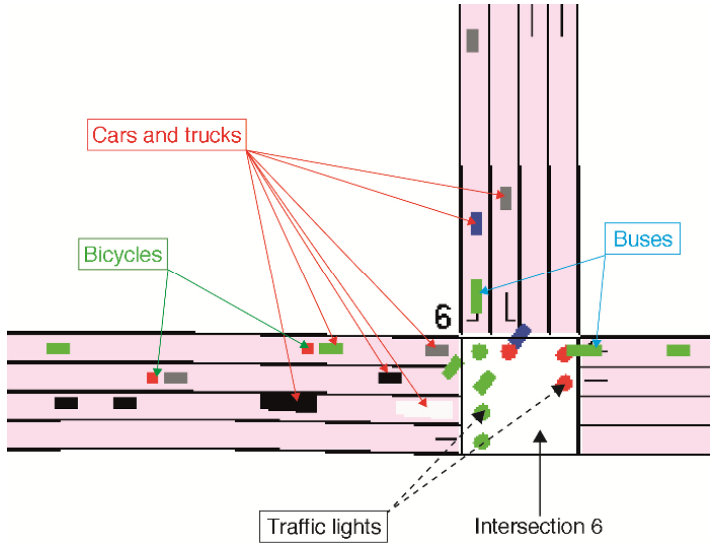


Figure 4.33. *The different types of vehicle in the model during the simulation*

You can choose **PROPERTIES** by right-clicking on one of the lanes of the junction between intersections. This will display its properties (Figure 4.34).

Figure 4.34. *Display showing the properties of a junction lane, in this case "Drivelane 24"*

This shows:

– **DRIVELANE n**: lane number;

– **PART OF**: road the lane junction is part of;

– **LEADS TO**: intersection the vehicles are coming from (gives the direction of traffic);

– **COMES FROM**: intersection the vehicles are heading towards (gives the direction of the traffic);

– **WAITING FOR TRAFFICLIGHT**: number of vehicles waiting in the lane;

– **DRIVELANE ALLOWS AUTOMOBILES**: type of vehicles the lane is designed for;

– Type of vehicles in the lane: located in the left pane. If **SHOW FREE SPACES** is ticked, it is possible to view the free spaces (empty inter-vehicle blocks).

Right-clicking on one of the nodes of the intersections will allow you to select **PROPERTIES**. This will display its properties (Figure 4.35) or give a two graph display: **TRACK ROADUSERS THAT CROSSED** displays the number of vehicles crossing the intersection as a function of the time elapsed (number of cycles) and **TRACK JUNCTION WAITING TIME** allows you to view the average waiting time for vehicles at the intersection as a function of the time elapsed (number of cycles).

A node at an intersection has the following properties:

– **JUNCTION n**: intersection number;

– **ROAD NORTH**: name and number of the road heading north from this intersection;

– **ROAD EAST**: name and number of the road heading east from this intersection;

– **ROAD SOUTH**: name and number of the road heading south from this intersection;

– **ROAD WEST**: name and number of the road heading west from this intersection;

– **JUNCTION HAS n TRAFFICLIGHTS**: number of traffic lights at this intersection;

– **JUNCTION IS n UNITS WIDE**: number of lanes, in width, available at this intersection;

– **TRACK ROADUSERS THAT CROSSED**: Displays the graph showing the number of vehicles;

– **TRACK JUNCTION WAITING TIME**: Displays the graph showing the average waiting time;

– **AVERAGE WAITING TIME**: displays the average waiting time;

– **SHOW OF LAST 1,000 ROADUSERS**: if ticked, this will display the average waiting time for the last 1,000 vehicles.

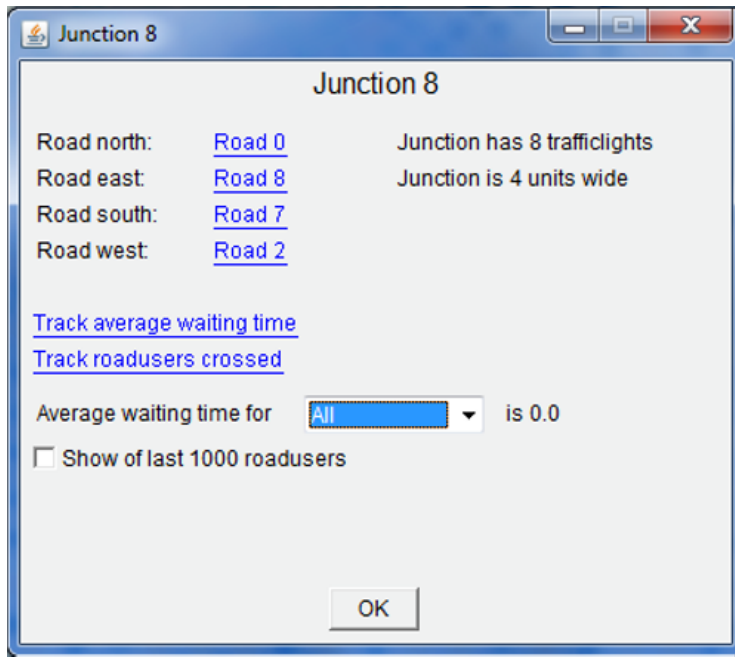


Figure 4.35. *Display showing the properties of a node at an intersection, in this case "Junction 8"*

COMMENT 4.6.– Certain items in these properties windows are written in blue and underlined. These are interactive links that display additional information, in relation to the chosen element.

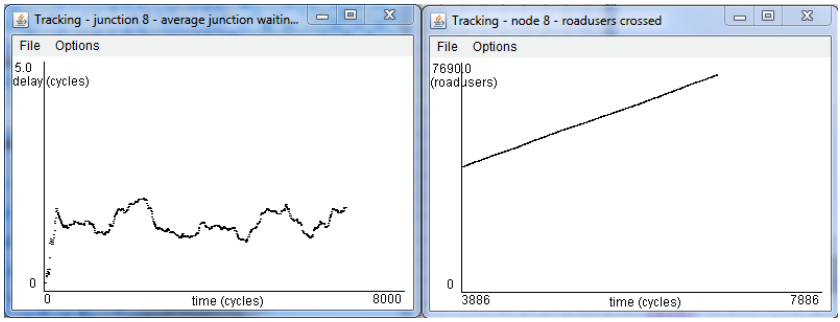


Figure 4.36. *Two graphs : average waiting time for vehicles at the intersection as a function of the time elapsed (on the left) and the number of vehicles having crossed the intersection as a function of the time elapsed (on the right)*

The “Edge nodes” have different properties:

– **CONNECTS**: road the node is connected to;

– **WITH**: intersection the road is connected to;

– **WAITING IN QUEUE**: number of vehicles waiting in the line as a function of the type of vehicle (**ALL**, **CAR**, **BUS**, **BICYCLE**);

– **SPAWNFREQUENCY FOR**: frequency of vehicles generated as a function of the type of vehicle (between 0 and 1 – from 0 to 100%);

– **SET**: button for confirming the frequency input;

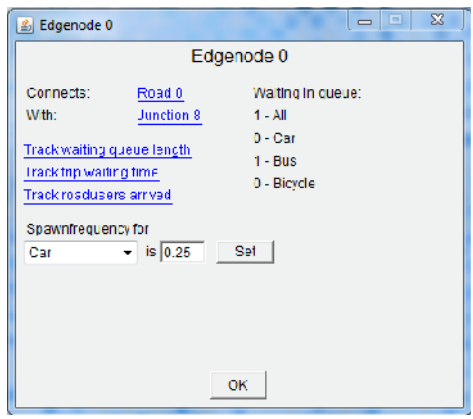


Figure 4.37. *Display showing the properties of an “Edge node”, in this case “Edgenode 0”*

– **TRACK WAITING QUEUE LENGTH**: length of the queue as a function of time elapsed (number of cycles);

– **TRACK TRIP WAITING TIME**: average waiting time for a journey as a function of time elapsed (number of cycles);

– **TRACK ROADUSERS ARRIVED**: number of vehicles arriving as a function of the time elapsed (number of cycles).

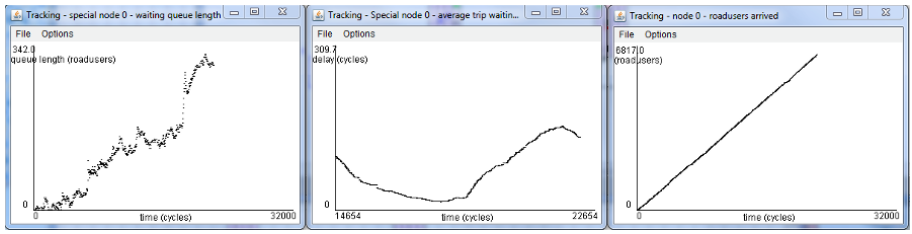


Figure 4.38. *The graphs available from the "Edge node"*

The three graphs in Figure 4.38 can also be accessed by right-clicking on the node.

During a simulation with a model, it is possible to adjust several parameters.

We will start by adjusting **SPAWNFREQUENCY FOR**, available in the properties panel for *"Edgenodes"*. As a function of the type, you can enter a value corresponding to the frequency that you wish to see generated by the node.

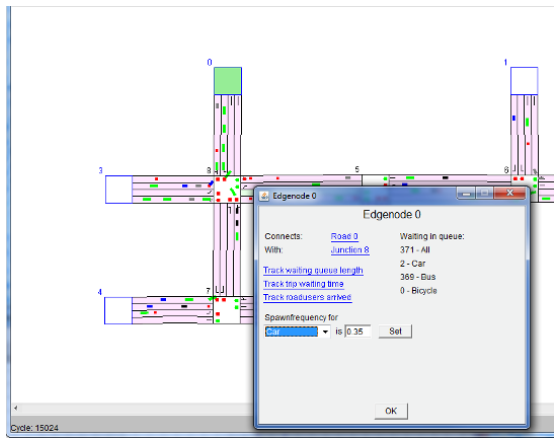


Figure 4.39. *The properties panel for the node "Edgenode 0" in our model after modification at the end of roughly 15,000 cycles*

In our model, for example, for the node EDGENODE 0, if you adjust the default values and enter 0.65 for BUS, 0.35 for CAR and 0.0 for BICYCLE (don't forget to confirm by clicking on the SET button), you will obtain the results shown in Figure 4.40, after roughly 10,000 cycles.

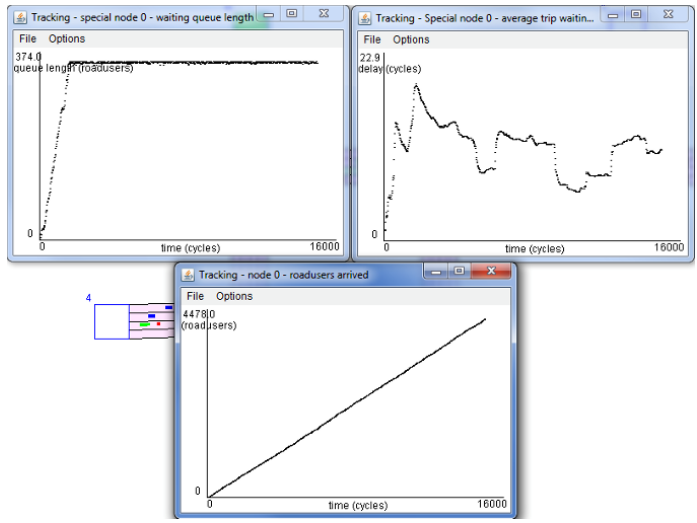


Figure 4.40. *The three statistical graphs for the node EDGENODE 0 in our model after roughly 15,000 simulation cycles*

The most important parameter corresponds to controlling traffic lights at each of the intersections. For this, we have a number of options within the GLD, contained in the **OPTIONS** menu, accessible by selecting **TRAFFIC LIGHT CONTROLLER**.

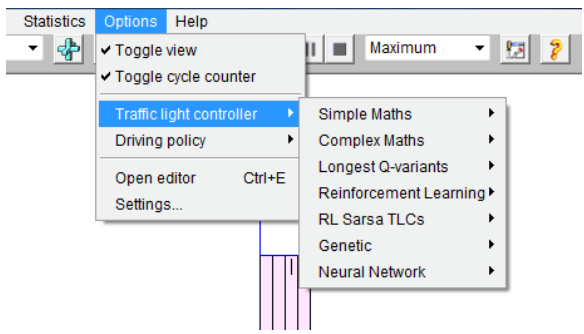


Figure 4.41. *The categories of options available for managing traffic lights from the OPTIONS menu*

I would invite you to consult section 5b, TRAFFIC LIGHT CONTROLLERS, in the GLD documentation for details relating to the options available for managing signals.

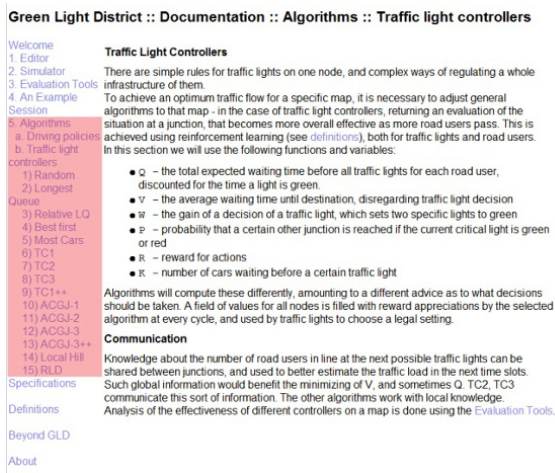


Figure 4.42. *Section 5b of the GLD documentation relating to traffic light options*

We will now try to modify the management of lights by selecting a management method based on the largest number of cars, **MOST CARS**, in **SIMPLEX MATHS** and we will compare this to **RANDOM**, again in **SIMPLEX MATHS**.

Figure 4.43 shows the results at the end of 2,000 cycles for the average waiting time at the intersections in our model (**STATISTICS** menu, **TRACK** option, then **AVERAGE JUNCTION WAITING TIME**).

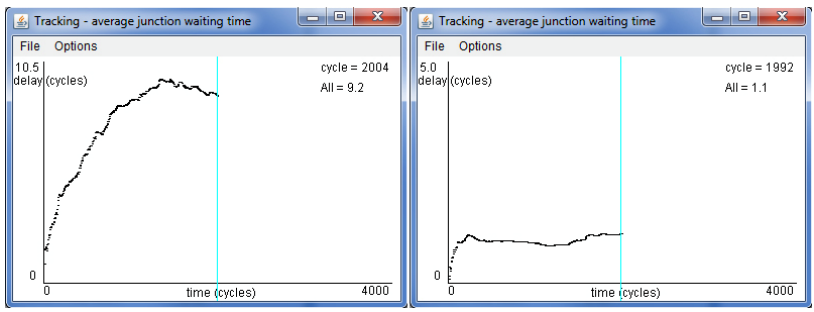


Figure 4.43. *The average waiting times at intersections in our model with a random management method (RANDOM – on the left) and using a method with the most cars (MOST CARS – on the right)*

We are able to note striking differences depending on the management method.

COMMENT 4.7.– It is possible to configure certain options for managing traffic lights. In this case, a dialog box with the appropriate input fields will appear when the user has made one of these choices.

Another parameter is the driving policy, which can be accessed by going to the **OPTIONS** menu and selecting **DRIVING POLICY**. Four options are available:

– **NORMAL SHORTEST PATH**: The vehicle selects the shortest path to go from their departure point to their destination, irrespective of the intersections and the traffic lights that they will have to pass through;

– **LEAST BUSY SHORTEST PATH**: The vehicle will take the shortest path by taking into account the waiting time for each of the lanes, which could be blocked;

– **AGGRESSIVE**: The vehicle will try to limit the journey time between their departure point and their destination;

– **COLEARNING**: The vehicle selects their traffic lane in order to reduce the likely waiting time at the next junction as much as possible. Their choice is based on intelligent, distributed, multi-agent algorithms that enable traffic lights to communicate with each other, for which road users are continuously made aware of the waiting times. This option is only available with certain methods of traffic management (learning).

4.5.4.3. *Advanced use of the editor*

We will now return to our editor and take a closer look at its editing features.

You can access your editor from *"GLDSim"* by selecting **OPEN EDITOR** (**CTRL E**) from the **OPTIONS** menu.

You can also close *"GLDSim"* and re-open your model using *"GLDEdit"*.

We will start by deleting the lanes between the different intersections in our model in order to obtain the network from Figure 4.44.

Two traffic lanes were deleted between nodes 7 and 9 as well as 5 and 9.

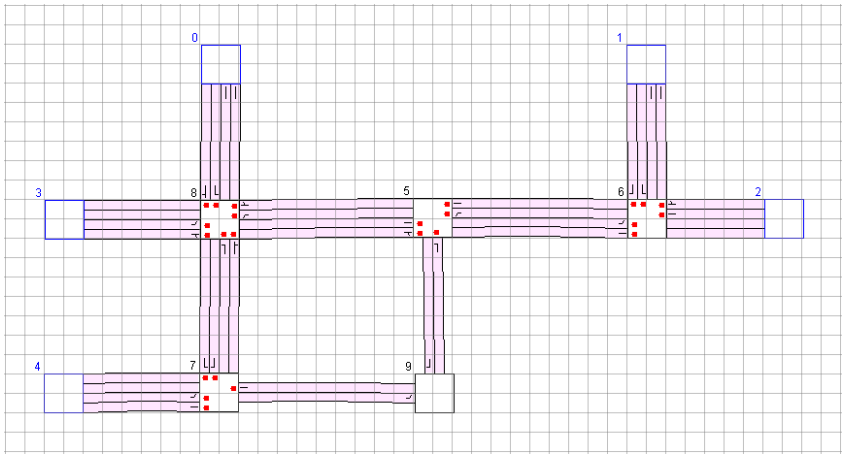


Figure 4.44. *My example model showing the lanes deleted between nodes 7, 9 and 5*

In order to delete these nodes, once you have opened the model in the editor:

– right click on the section where you want to delete the lanes and then select **PROPERTIES**;

– in the list **LANES TO**, select the lane that you want to delete, then click on the **DELETE DRIVELINE n.**

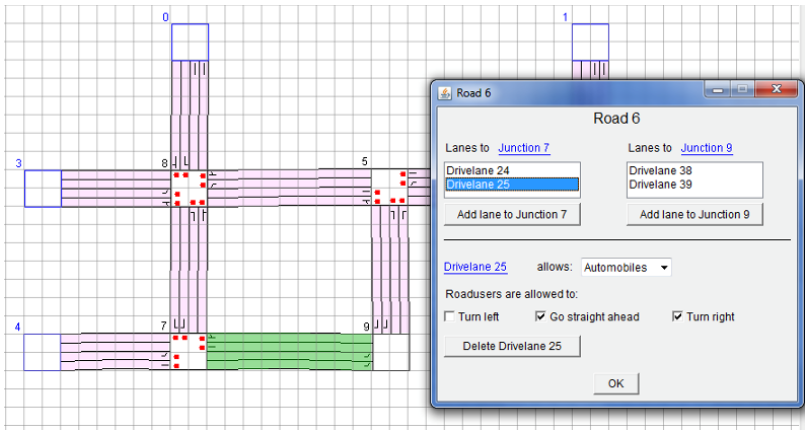


Figure 4.45. *The dialog box for the properties of the junction and its DELETE DRIVELANE button. Here, the lane "Drivelane 25" in the junction "Road 6" has been selected. We can see the corresponding interactive link, underlined and in blue. For a color version of this figure, see www.iste.co.uk/reveillac/modeling2.zip*

If you are unsure of the lane, you can verify it by clicking on the corresponding link, underlined and in blue, and it will be highlighted in green in your model. In this instance, it can be deleted by selecting **DELETE THIS DEVICE**.

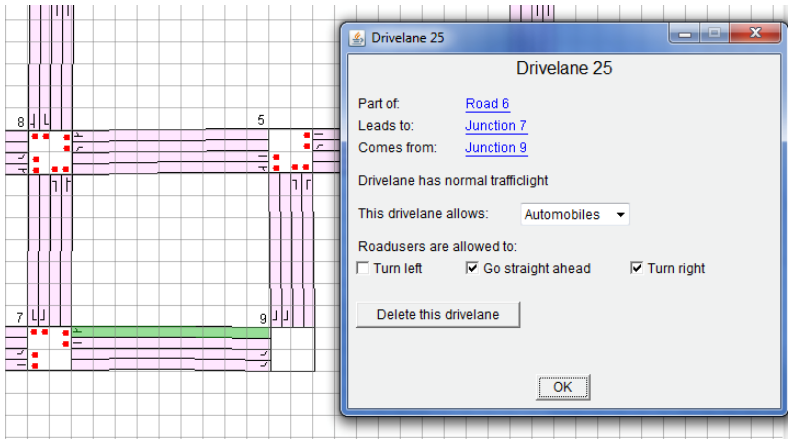


Figure 4.46. *The dialog box for lane properties, here "Drivelane 25", and its DELETE THIS DRIVELANE button*

Repeat the same steps to delete the other three lanes.

The GLD editor allows you to restrict lanes to a certain type of vehicle.

Let's now modify our model to link green lanes to buses (see Figure 4.47).

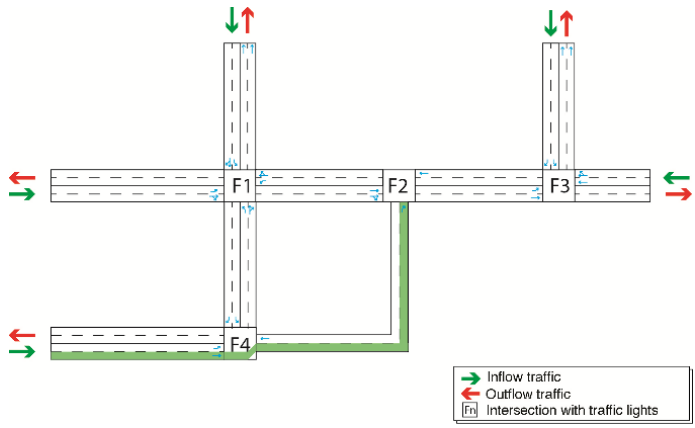


Figure 4.47. *The plan for our model showing the bus lanes (in green). For a color version of this figure, see www.iste.co.uk/reveillac/modeling2.zip*

Right-click on the relevant junction, then select **PROPERTIES**. Select the lane in **LANES TO**, then assign it **BUS** using the drop-down list **ALLOWS**.

Repeat the same steps twice for the other sections. You should obtain a model similar to the one in Figure 4.48.

The lanes restricted to buses will have changed color and should now be orange instead of pink.

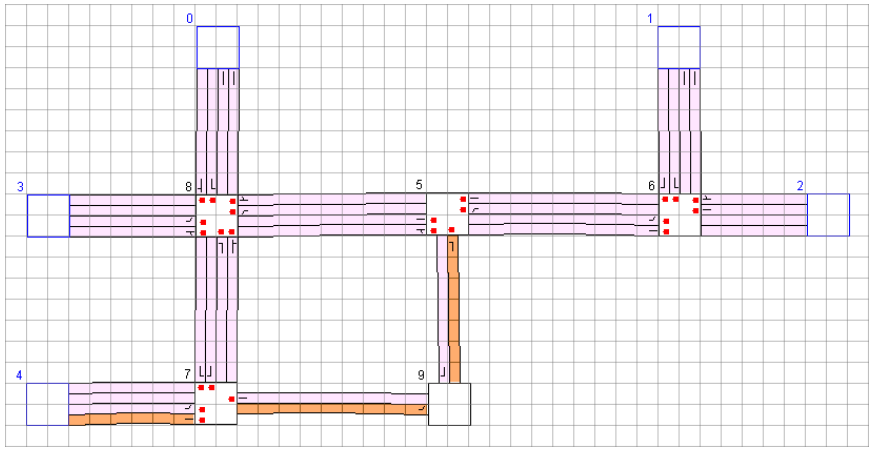


Figure 4.48. *The model featuring orange lanes restricted to buses. For a color version of this figure, see www.iste.co.uk/reveillac/modeling2.zip*

Save (menu **FILE**, then **SAVE** or **SAVE AS**) your model using a new name in order to save your modifications.

There is a highly significant configuration that I have not yet introduced, and this relates to the direction cars must travel in at each intersection and for each lane.

In the model, these direction indicators (the equivalent of white arrows, painted on the ground, in reality) are in the form of small acronyms within the lanes at the entry to an intersection.

In Figure 4.49, we can see these before nodes 5 and 6. They are self-explanatory.

They are generated by default when constructing a model but do not necessarily correspond to the way you want it to be.

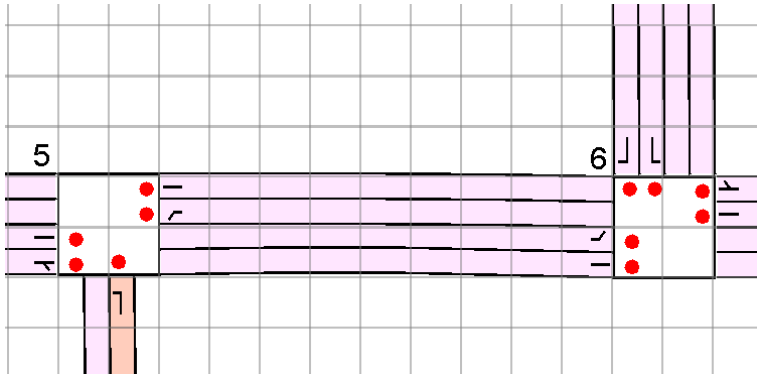


Figure 4.49. *A section of the model with nodes 5 and 6 surrounded by their direction indicators*

These can be easily modified using the GLD editor. For example, I am going to change the direction to take when a bus arrives from the south, moving towards intersection 5.

Instead of turning left, I want it to continue right towards node 6.

Right-clicking on the junction will display its properties. I will then select the lane, in **LANES TO**, for which I will specify only **TURN RIGHT** (tickbox).

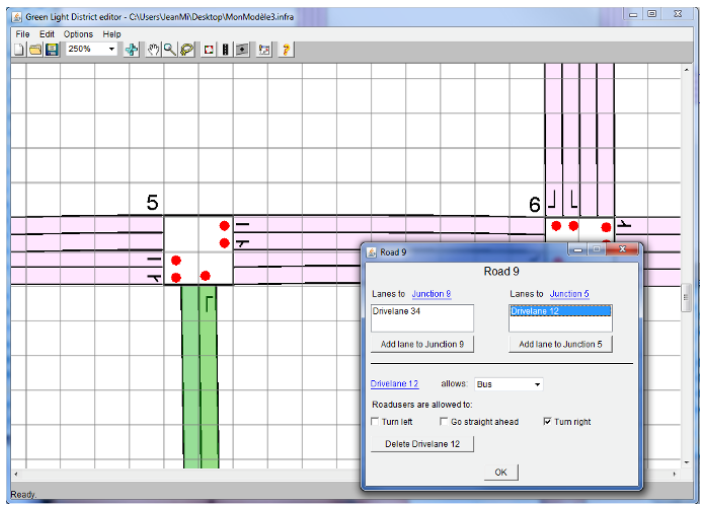


Figure 4.50. *The properties box with the modified direction indicators, TURN RIGHT, ticked, TURN LEFT, unticked, for the lane "Drivelane 12" of junction "Road 9"*

This offers the following possibilities, which can all be combined:

– **TURN LEFT**;

– **GO STRAIGHT AHEAD**;

– **TURN RIGHT**.

This allows us to obtain the direction indicator logos in Figure 4.51.

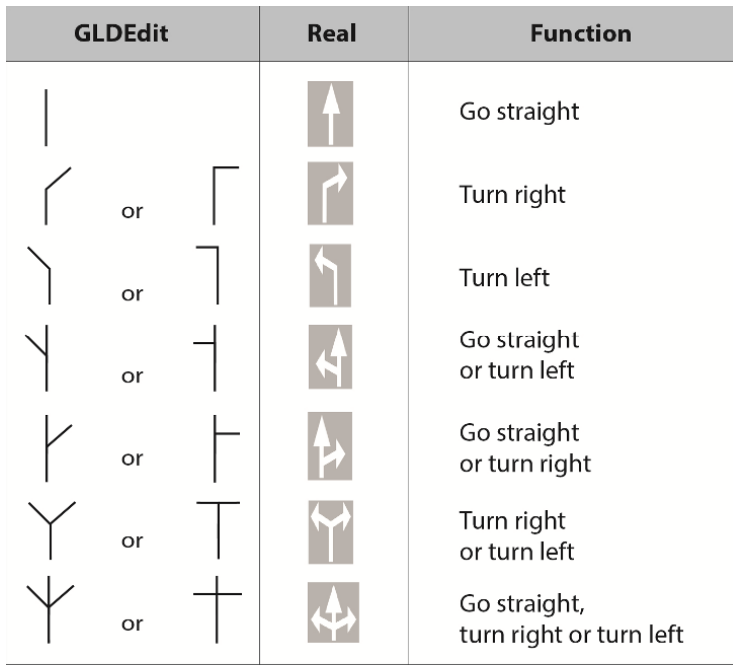


Figure 4.51. *The direction indicators in "GLDEdit"*

Save (menu **FILE**, then **SAVE** or **SAVE AS**) your model in order to save your changes.

4.5.4.4. *Simulating the modified model*

Open your modified model using the simulator and launch the simulation.

You should now see the bus traveling on the sections of the route that you have modified. These should also respect the direction indicators that you have specified.

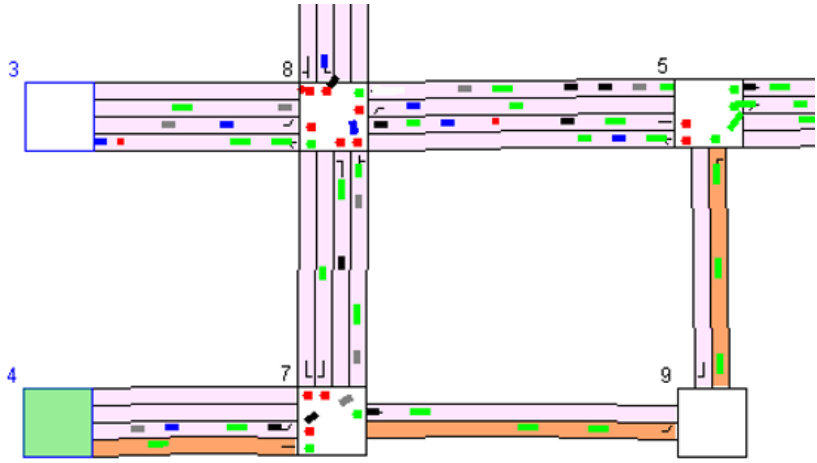


Figure 4.52. *Here we can note the green buses on the orange lanes, starting at node 4 and turning right at node 5. For a color version of this figure, see www.iste.co.uk/reveillac/modeling2.zip*

It might be interesting to have general statistical data for a model – you can access this feature by selecting **SHOW STATISTICS** from the **STATISTICS** menu.

Once it has been activated, a window will open featuring the **FILE** and **OPTIONS** menus.

In **FILE**, the **EXPORT** option will allow you to export the statistics file in *".dat"* format, or to close the window.

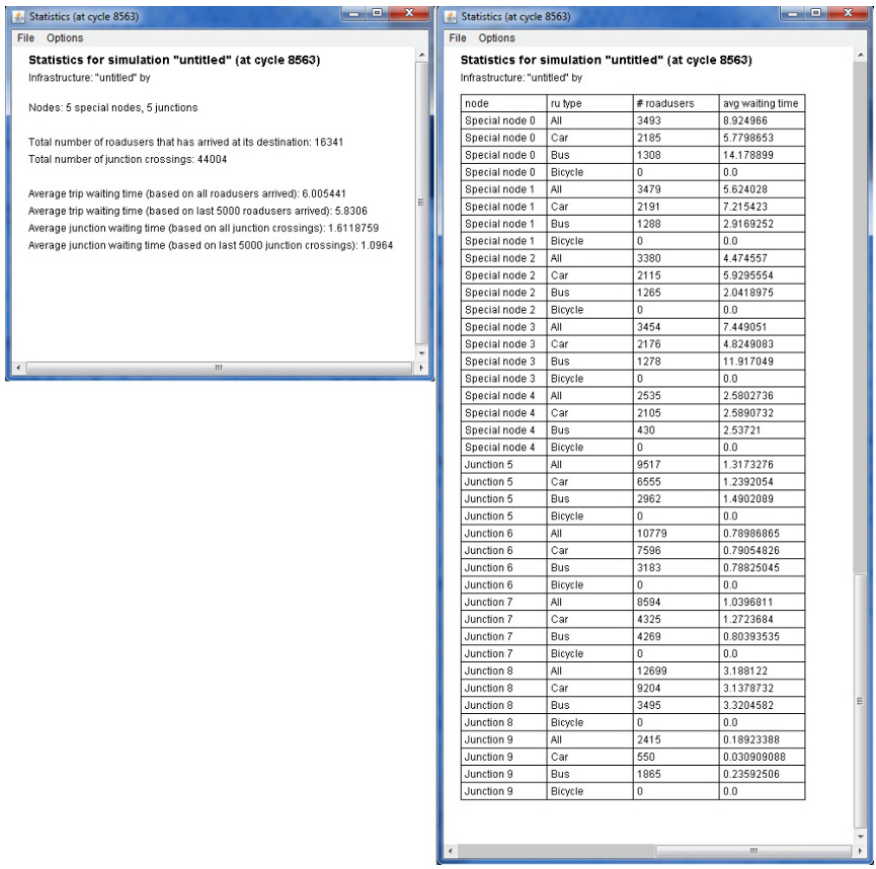
COMMENT 4.8.– A *".dat."* file is a data file (*".dat"* for data). In general, this type of file can be easily opened using a text editor such as Notepad in Microsoft Windows or TextEdit in Apple OSX. It is easy to use this data in Microsoft Excel using copy and paste, although in general these files are designed for use with specific programs.

The OPTIONS menu has three main functions:

– **REFRESH (CTRL R)**: refreshes the results in relation to the current simulation;

– **VIEW**: displays a summary of the statistics (**SUMMARY**) or a table showing the statistics (**TABLE**);

– **SHOW AVERAGE OF**: display the average for all vehicles since the start of the simulation using **ALL ROADUSERS** or for the last 1,000 using **LAST 1000 ROADUSERS.**

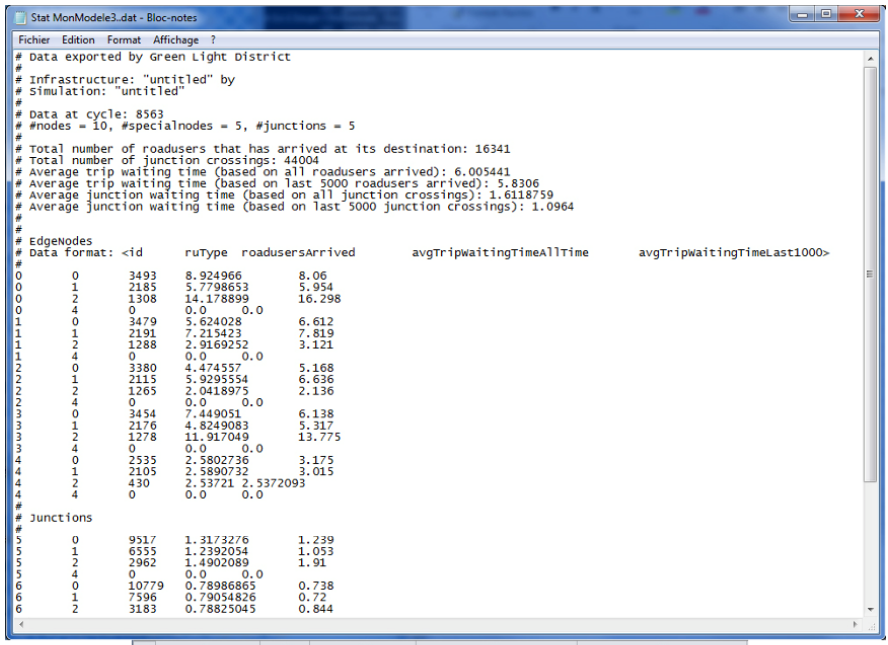


node	ru type	# roadusers	avg waiting time
Special node 0	All	3493	8.924966
Special node 0	Car	2185	5.7798653
Special node 0	Bus	1308	14.178899
Special node 0	Bicycle	0	0.0
Special node 1	All	3479	5.624028
Special node 1	Car	2191	7.215423
Special node 1	Bus	1288	2.9169252
Special node 1	Bicycle	0	0.0
Special node 2	All	3380	4.474557
Special node 2	Car	2115	5.9295554
Special node 2	Bus	1265	2.0418975
Special node 2	Bicycle	0	0.0
Special node 3	All	3454	7.449051
Special node 3	Car	2176	4.8249083
Special node 3	Bus	1278	11.917049
Special node 3	Bicycle	0	0.0
Special node 4	All	2535	2.5802736
Special node 4	Car	2105	2.5890732
Special node 4	Bus	430	2.53721
Special node 4	Bicycle	0	0.0
Junction 5	All	9517	1.3173276
Junction 5	Car	6555	1.2392054
Junction 5	Bus	2962	1.4902089
Junction 5	Bicycle	0	0.0
Junction 6	All	10779	0.78986865
Junction 6	Car	7596	0.79054826
Junction 6	Bus	3183	0.78825045
Junction 6	Bicycle	0	0.0
Junction 7	All	8594	1.0396811
Junction 7	Car	4325	1.2723684
Junction 7	Bus	4269	0.80393535
Junction 7	Bicycle	0	0.0
Junction 8	All	12699	3.188122
Junction 8	Car	9204	3.1378732
Junction 8	Bus	3495	3.3204582
Junction 8	Bicycle	0	0.0
Junction 9	All	2415	0.18923388
Junction 9	Car	550	0.030909088
Junction 9	Bus	1865	0.23592506
Junction 9	Bicycle	0	0.0

Figure 4.53. *The statistics window in SUMMARY mode (on the left) and TABLE mode (on the right)*

Figure 4.54 gives an example showing part of the data copied and pasted into Microsoft Excel from a *".dat"* folder, exported by the simulator.

These are the main features of GLD. Developers are currently seeking ways to make improvements or to increase its capabilities. Consult the links at the end of this work for further information.



Stat MonModele3_dat - Bloc-notes

Fichier Edition Format Affichage ?

```
# Data exported by Green Light District
#
# Infrastructure: "untitled" by
# Simulation: "untitled"
#
# Data at cycle: 8563
# #nodes = 10, #specialnodes = 5, #junctions = 5
#
# Total number of roadusers that has arrived at its destination: 16341
# Total number of junction crossings: 44004
# Average trip waiting time (based on all roadusers arrived): 6.005441
# Average trip waiting time (based on last 5000 roadusers arrived): 5.8306
# Average junction waiting time (based on all junction crossings): 1.6118759
# Average junction waiting time (based on last 5000 junction crossings): 1.0964
#
#
# EdgeNodes
# Data format: <id      ruType  roadusersArrived        avgTripWaitingTimeAllTime       avgTripWaitingTimeLast1000>
#
0       0       3493    8.924966        8.06
0       1       2185    5.7798653       5.954
0       2       1308    14.178899       16.298
0       4       0       0.0     0.0
1       0       3479    5.624028        6.612
1       1       2191    7.215423        7.819
1       2       1288    2.9169252       3.121
1       4       0       0.0     0.0
2       0       3380    4.474557        5.168
2       1       2115    5.9295554       6.636
2       2       1265    2.0418975       2.136
2       4       0       0.0     0.0
3       0       3454    7.449051        6.138
3       1       2176    4.8249083       5.317
3       2       1278    11.917049       13.775
3       4       0       0.0     0.0
4       0       2535    2.5802736       3.175
4       1       2105    2.5890732       3.015
4       2       430     2.53721 2.5372093
4       4       0       0.0     0.0
#
# Junctions
#
5       0       9517    1.3173276       1.239
5       1       6555    1.2392054       1.053
5       2       2962    1.4902089       1.91
5       4       0       0.0     0.0
6       0       10779   0.78986865      0.738
6       1       7596    0.79054826      0.72
6       2       3183    0.78825045      0.844
```

	A	B	C	D	E
1	Data format: <id	ruType	roadusersArrived	avgTripWaitingTimeAllTime	avgTripWaitingTimeLast1000>
2	#				
3	0	0	3493	8.924966	8.06
4	0	1	2185	5.7798653	5.954
5	0	2	1308	14.178899	16.298
6	0	4	0	0.0	0.0
7	1	0	3479	5.624028	6.612
8	1	1	2191	7.215423	7.819
9	1	2	1288	2.9169252	3.121
10	1	4	0	0.0	0.0
11	2	0	3380	4.474557	5.168
12	2	1	2115	5.9295554	6.636
13	2	2	1265	2.0418975	2.136
14	2	4	0	0.0	0.0
15	3	0	3454	7.449051	6.138
16	3	1	2176	4.8249083	5.317
17	3	2	1278	11.917049	13.775
18	3	4	0	0.0	0.0
19	4	0	2535	2.5802736	3.175
20	4	1	2105	2.5890732	3.015
21	4	2	430	2.53721	2.5372093
22	4	4	0	0.0	0.0
23					

Figure 4.54. *A ".dat" file (top) and the data in Microsoft Excel (bottom)*

4.6. AnyLogic

This program is universal – it can be adapted to practically all domains or, alternatively, a simulation model can be created (see Volume 1, section 10.4.3.4). In this chapter, we will concern ourselves with how it might be used for traffic management.

In its 7.3 version, AnyLogic features a *"Road Traffic Library"* designed specifically for road network models and simulations.

In order to do this, the application follows a construction process made up of several stages:

– importing a background map or an image of a plan;

– tracing and configuration of traffic lanes as well as their eventual intersections;

– design and configuration of the organigram for generating and controlling the flow of vehicles;

– adding traffic lights, pedestrian walkways, car parks, public transport vehicles, and configuration;

– 2D simulation;

– 3D simulation;

– results analysis.

We will create a short example showing some of these stages in order to give you a chance to assess the program's features, ergonomics and flexibility.

4.6.1. *Downloading AnyLogic*

Before we begin, download the free version of AnyLogic at[7]: www.anylogic.com/downloads.

Select your operating system, Microsoft Windows (x32 or x64), Mac OSX or Linux and select "FREE PLE" (Personal Learning Edition).

7 At the time of writing, this link is active and the PLE version is free to download. Given the volatility of these links and the fact that the terms and conditions are subject to change, should you encounter any problems, search for "AnyLogic" using your preferred search engine.

Figure 4.55. *The AnyLogic downloads page*

Information on how to active the program is available via a link on the page.

4.6.2. *Our example*

For our background image, we will take an aerial view of a city taken from Google Maps showing several streets, with at least one intersection. This will be used for tracing our road network.

Figure 4.56. *Aerial image from our example (Source: Google Maps)*

4.6.2.1. *Capturing the background image*

The easiest way to obtain your image is to use a screenshot.

On Mac: Press CMD SHIFT 4 and the cursor will take the shape of a cross (target). Select the area by dragging and dropping, let go of the click, and a *".png"* image will appear on your desktop with the name *"Screen Shot YEAR-MONTH-DAY at HOUR.MINUTE.SECOND AM/PM"*.

On PC[8]: Click on the START MENU then enter Snipping Tool in the search bar and confirm by pressing ENTER.

Click on the triangle of the drop-down menu NEW in the SNIPPING TOOL dialog box which appears. Select RECTANGULAR SNIP, then, using the mouse to drag-and-drop, specify the area you wish to capture.

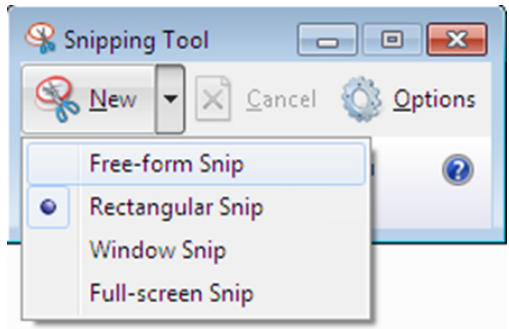


Figure 4.57. *The SNIPPING TOOL dialog box in Microsoft Windows 7*

In the **FILE** menu in the window which opens, select **SAVE AS** then, after having given a name, a file type (**PNG** or **JPG**). Once you have specified the storage location, save your image by clicking on the **SAVE** button.

4.6.2.2. *Network modeling*

After installation, launch the program, then select **CREATE A MODEL** on the welcome screen.

8 Using Microsoft Windows VISTA or Windows 7 and above. Otherwise, download a free screenshot program such as: Gadwin PrintScreen, ScreenHunter, ScreenHotPlus, etc.

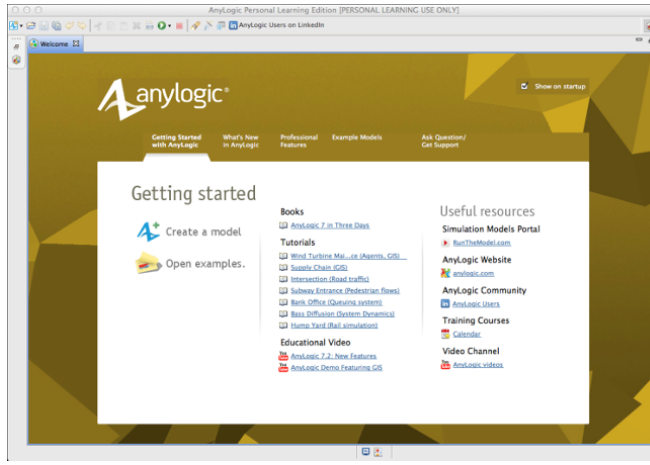


Figure 4.58. *The AnyLogic welcome screen*

A dialog box will open. Give your model a name and specify a storage location, then click on **FINISH**.

Click on the **PALETTE** tab, located beneath the main toolbar, then select the **PRESENTATION** icon in the vertical toolbar (Figure 4.59).

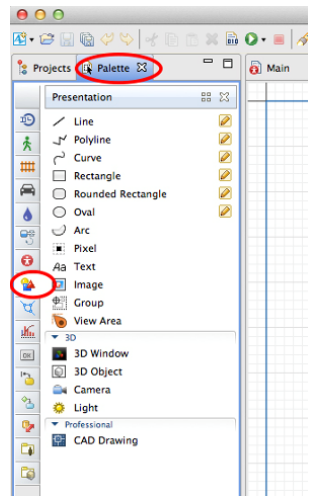


Figure 4.59. *The PALETTE tab and its PRESENTATION tools*

In the tools for the **PRESENTATION** palette, select **IMAGE** and drag it into the **MAIN** window inside the rectangular area defined by a marker (Figure 4.60).

A dialog box will ask you to select a file. Select your screenshot and click on the **OPEN** button.

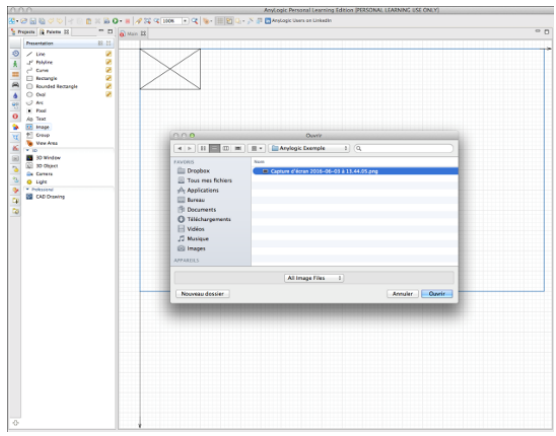


Figure 4.60. *Selecting the captured image to be used as your background. Note the area defined by the marker xy*

Position the image so that its top-left corner is where the marker is (Figure 4.61). Finally, resize the image by pulling at one of the corners.

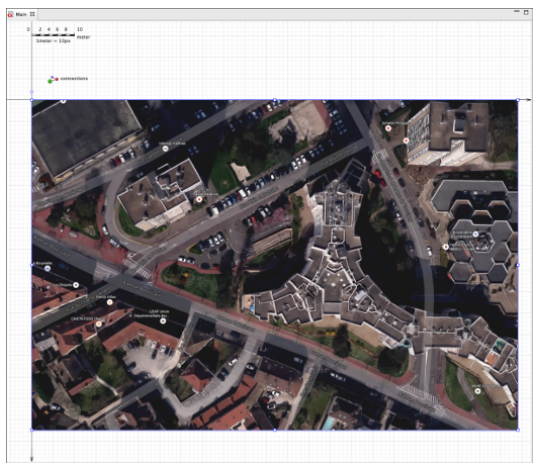


Figure 4.61. *The image positioned where the marker is in the MAIN window. We can see the scale indicator at the top*

Above the image, a scale indicator will appear. Once this has been selected, you can expand it or reduce it in order to adapt the scale to your image, if the size correspondence is poor.

COMMENT 4.9.– In the main horizontal toolbar, located beneath the menu, there is an option to vary the display scale of your model (from 25 to 4000%) in the drop-down menu next to the magnifying tool (ZOOM IN).

In the vertical toolbar in the **PALETTE** tab, select **ROAD TRAFFIC LIBRARY** (black icon in the shape of a small car).

Double-click on the **ROAD** tool then click in your image to trace a first street, from point to point (click to click).

Double-click to complete your route.

COMMENT 4.10.– This route tool works in the same way as the pen tool in certain graphics programs such as Adobe Illustrator. This allows us to create curves (splines, Bézier curves) for routes containing non-rectilinear sections.

A dialog box will open, recommending that you change the scale (4 pixels per meter). Confirm by clicking **YES**.

Clicking on the route that you have traced will bring up the parameters for the network (**ROAD NETWORK**) in the **PROPERTIES** window.

It might require several clicks, but you should be able to move, in a loop, from the properties of the road (**ROAD**), to those of the image and then the network.

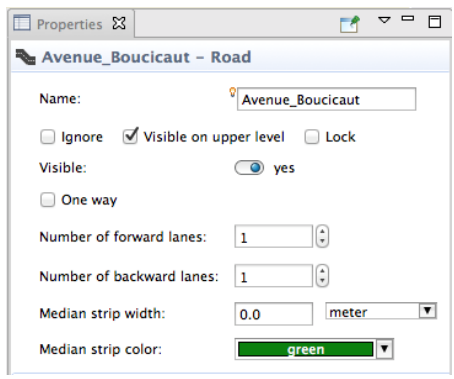


Figure 4.62. *The properties of the road (ROAD) including its name (in this case, "Avenue Boucicaut") and the number of lanes (in this case, 1 and 1)*

In **ROAD NETWORK**, modify the width of the lanes (**LANE WIDTH**). 3.5 m is the standard width.

In **ROAD**, name your street using the entry field **NAME** (spaces are not allowed) and specify the number of forward (**NUMBER OF FORWARD LANES**) and backward (**NUMBER OF BACKWARD LANES**) lanes.

You can determine where the lane is forward or backward using the route arrows.

Figure 4.63. *The route (one lane to the right and one to the left) in our model and its direction (in this instance, from left to right)*

We will now design another road, cutting across the first, similar to the previous road but whose last point (end point of the route) will be positioned on the central line of the road already present (Figure 4.64). This point will define where the two roads cross. Finish by naming the second road and specifying the number of lanes.

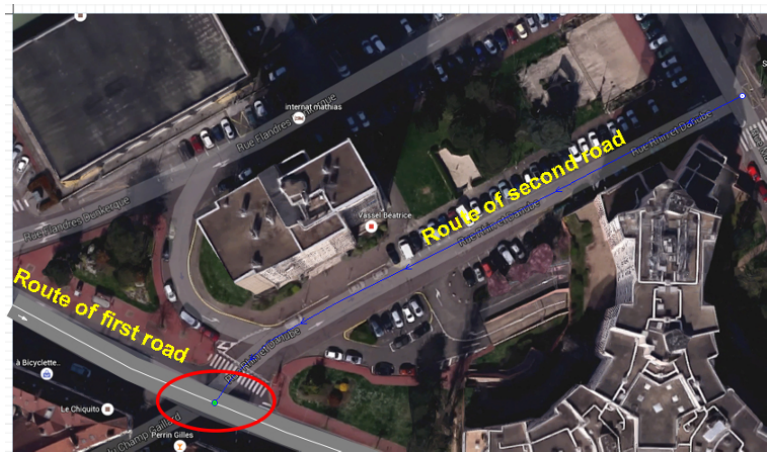


Figure 4.64. *The two roads and the point where the routes cross (green dot). For a color version of this figure, see www.iste.co.uk/reveillac/modeling2.zip*

COMMENT 4.11.– In the properties window for a road, you can tick the box ONE WAY to make your road one-way, should you so wish.

When creating an intersection, connected roads are divided into several sections. In our example, the first road is split into two parts (Figure 4.65).

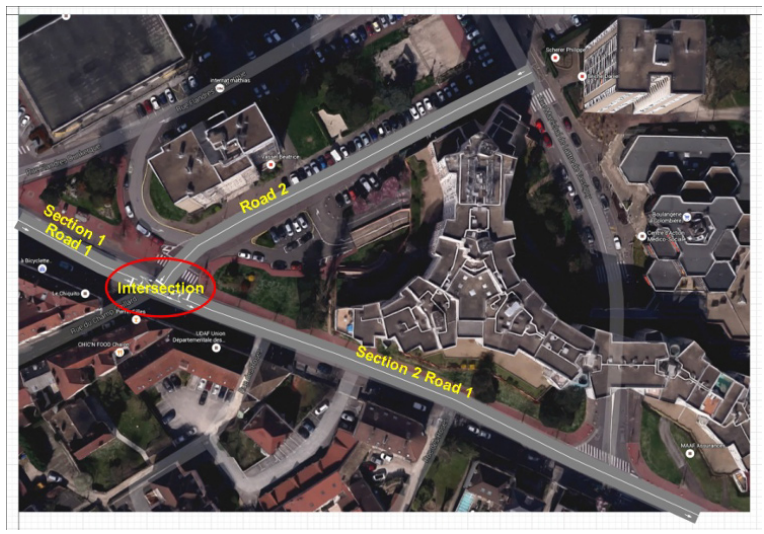


Figure 4.65. *The first road, divided into two sections, on both sides of the intersection*

It will be necessary to bring up the properties for each of the sections of the road, by selecting them, in order to rename them. Generally, for ease of use, we use the cardinal points connected to street names. In my model, for example:

– Section 1 Road 1: “avenue_boucicaut_SOUTH”;

– Section 2 Road 1: “avenue-Boucicaut_NORTH”;

– Road 2: “rue Rhin_Danube”.

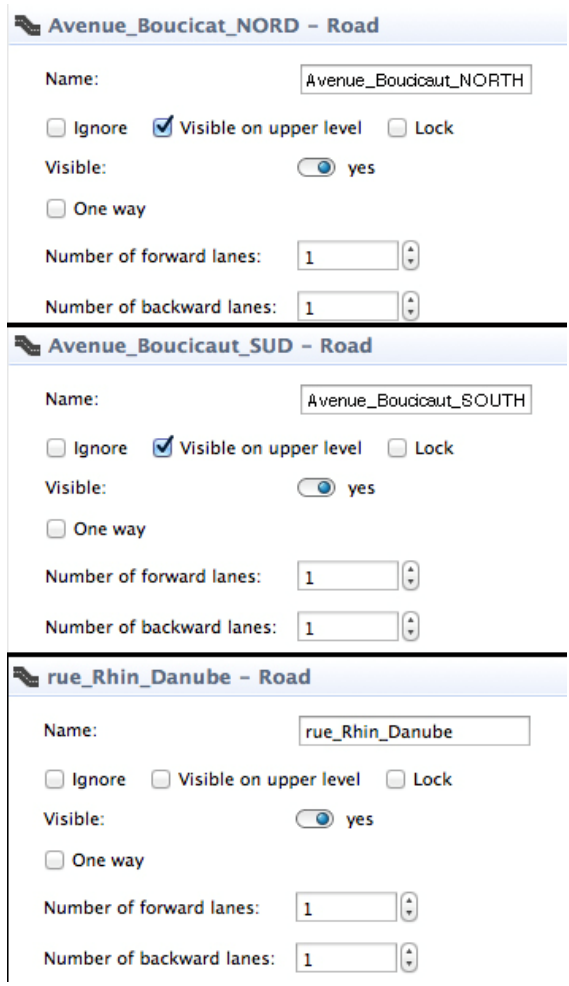


Figure 4.66. *The three properties windows for my three road segments : “Avenue_Boucicaut_NORTH”, “Avenue_Boucicaut_ SOUTH” and “Rue Rhin_Danube”*

4.6.2.3. *Generating and implementing road traffic*

In order to introduce vehicles into our model, we will build several organigrams grouping together the visual features linked to their creation and management.

Each of the entryways will have a source of cars traveling in a direction that we will be able to configure. The traffic plan to create is the one in Figure 4.67.

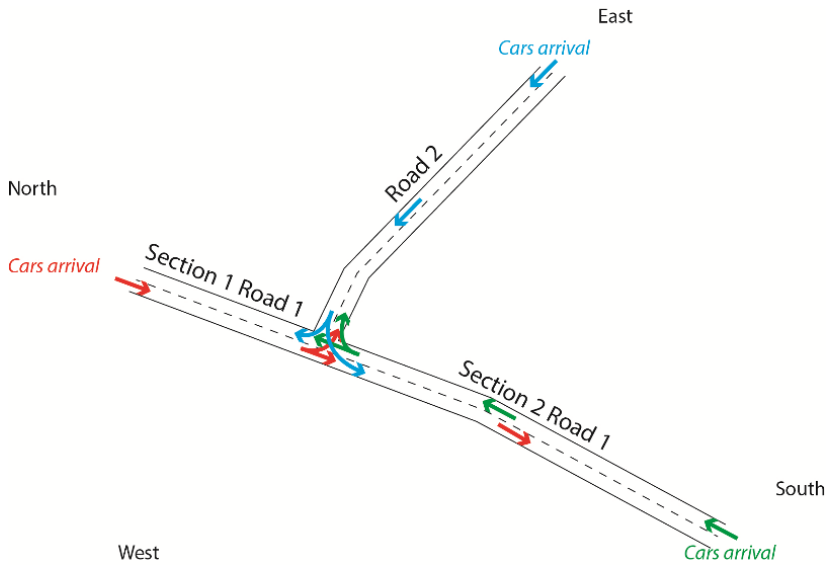


Figure 4.67. *The traffic plan for our example. For a color version of this figure, see www.iste.co.uk/reveillac/modeling2.zip*

You will be able to see that the vehicles arriving from the east can travel north or south, vehicles arriving from the south can travel east or north and vehicles arriving from the north can travel south or east.

To specify these constraints, move your cursor either above or below your plan in the **MAIN** window.

From the **ROAD TRAFFIC LIBRARY** in the **PALETTE** tab, drag and drop a **CAR SOURCE** block, then a **CAR MOVE TO** block and lastly a **CAR DISPOSE** block.

When you have moved them to **MAIN**, it will be possible to create links between those close to each other.

COMMENT 4.12.– In order to delete a link, left-click to select it (the surrounding points will become blue) then right-click followed by DELETE. In order to create a link, double-click on the first connecting point (green point) then drag towards the second connecting point (green point) and confirm by left-clicking.

This should enable you to obtain the organigram from Figure 4.38 with the three connected blocks.

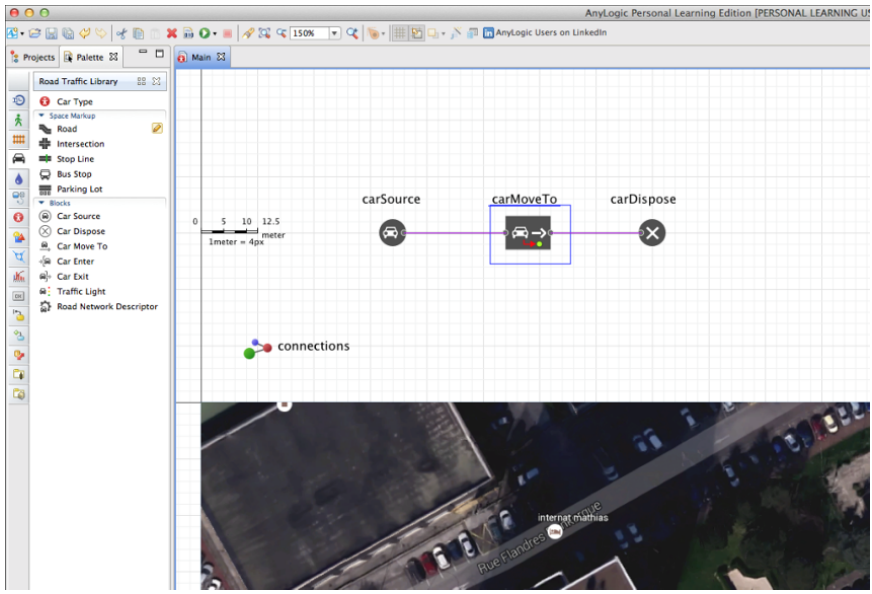


Figure 4.68. *The 3 blocks taken from the ROAD TRAFFIC LIBRARY, moved to the MAIN window and connected*

We will now configure each one:

– click on the **CARSOURCE** block, then in the **PROPERTIES** window, select **RATE** in the **ARRIVALS DEFINED** BY field;

– enter 750 **PER HOUR** in **ARRIVAL RATE**;

– select the north section of your n°1 road for the **ROAD** field;

– in **NAME**, enter “Veh_NORTH”.

You have just specified that a car will arrive from the north from this vehicle source every 15 seconds.

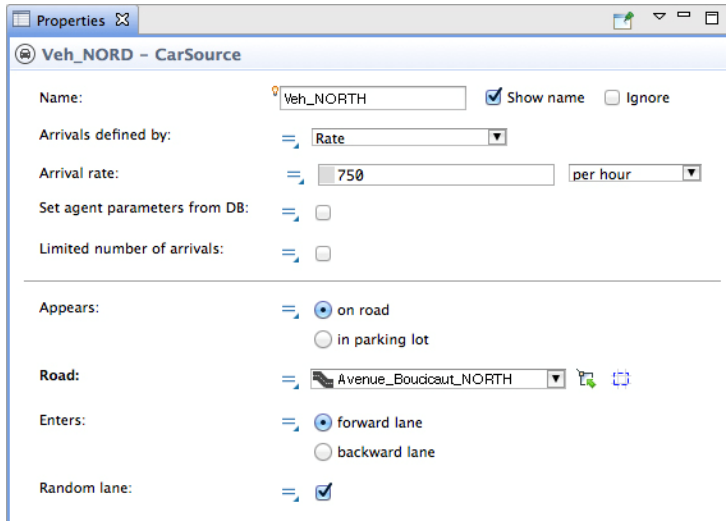


Figure 4.69. *The properties of the CAR SOURCE block, now named "Veh_NORTH"*

– click on **CARMOVETO** to display its properties;

– in the **NAME** field, change the name to "carMoveTo_SOUTH" and in the **ROAD** field, select the section of road located towards the south.

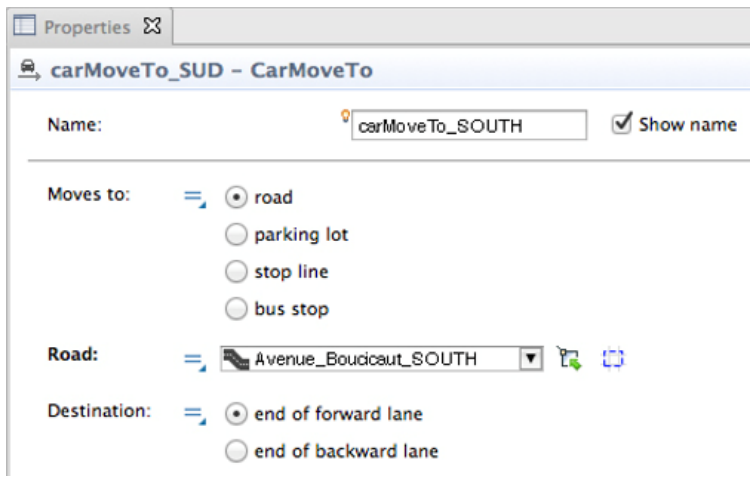


Figure 4.70. *The properties of the CARMOVETO block, now named "carMoveTo_SOUTH"*

By configuring in this way, you indicate that the vehicles arriving from the north will automatically travel towards the south section of your road.

Consider saving your model by selecting **SAVE AS** from the **FILE** menu. Enter a name in **MODEL NAME**, select a storage location in **LOCATION** or by using the **BROWSE** button, then click on the **FINISH** button to confirm.

4.6.2.4. *Test no.1 of the model simulation*

It is time now to test the first studies carried out using our model in order to ensure that it is working properly.

Select **RUN** from the **MODEL** menu or click on the **RUN** icon (white triangle on a green circle) from the horizontal toolbar.

Wait a few seconds. The simulator window, containing a **RUN** button below the name of your model, should appear in the foreground.

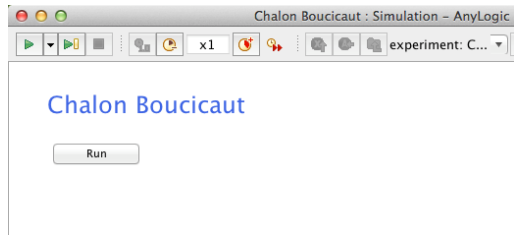


Figure 4.71. *The simulator window featuring its RUN button below the name of the model, in this case "Chalon Boucicaut"*

Click on **RUN** to launch your simulation. You will be able to expand the window in order to see the whole of your model.

The main functions of the simulator toolbar are explained in Figure 4.72.

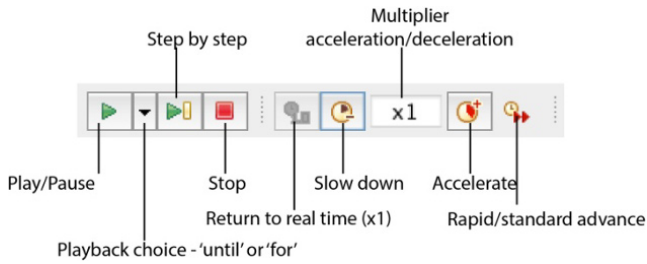


Figure 4.72. *The main functions of the simulator toolbar*

– Play/Pause: launch the simulation or restart it after pausing – pause the simulation;

– Playback choice – "until" or "for": drop-down menu enabling you to select normal playback (**RUN**), playback until a certain time or date (**RUN UNTIL**) or playback for a precise length of time (**RUN FOR**), for a chosen unit (years, months, weeks, days, hours, minutes, seconds, milliseconds);

– Step by step: Advance the simulation by one step for each click;

– Stop: stop the simulation and return to the window with the **RUN** button;

– Return to real time: play the simulation in real time;

– Slow down: slow the simulation by a factor equal to a fraction of real time (1/2, 1/5, 1/10, 1/25, 1/50, 1/100, 1/250, 1/500);

– Multiplier acceleration/deceleration: displays the value of the deceleration or acceleration factor;

– Accelerate: accelerates the simulation by a factor equal to a multiple of real-time (2, 5, 10, 25, 50, 100, 250, 500);

– Rapid/standard advance: increase the speed to maximum or return to the previous speed.

Vehicles are represented by small colored rectangles. They should travel from north to south.

Figure 4.73. *Window showing the model during simulation. In this instance, we can see six vehicles (blue, green, cyan, green, green and red) traveling from north to south on road no.1 section 1 and 2. For a color version of this figure, see www.iste.co.uk/reveillac/modeling2.zip*

COMMENT 4.13.– When you launch the simulator from the editor, if AnyLogic detects any errors, a dialog box will open with a message informing you of the nature of the problem or problems encountered. These errors often relate to direction, choice of roads or logic within the organigrams.

4.6.2.5. *Adding traffic*

We will now concern ourselves with redirecting our vehicles when they reach the intersection. For the purposes of this example, 60% of the traffic will be traveling south and 40% will be traveling east, that is towards road no. 2.

In order to apply this restriction, we will use a conditional function for redirecting *(aiguillage)* vehicles.

In the **PALETTE** tab, select the **PROCESSING MODELLING LIBRARY** (icon in the shape of a watch).

Drag a block **SELECT OUTPUT** next to your organigram.

Now open the **ROAD TRAFFIC LIBRARY** and add a **CAR MOVE TO** block and a **CAR ORDER.**

Delete and create the connections in order to obtain the organigram in Figure 4.74.

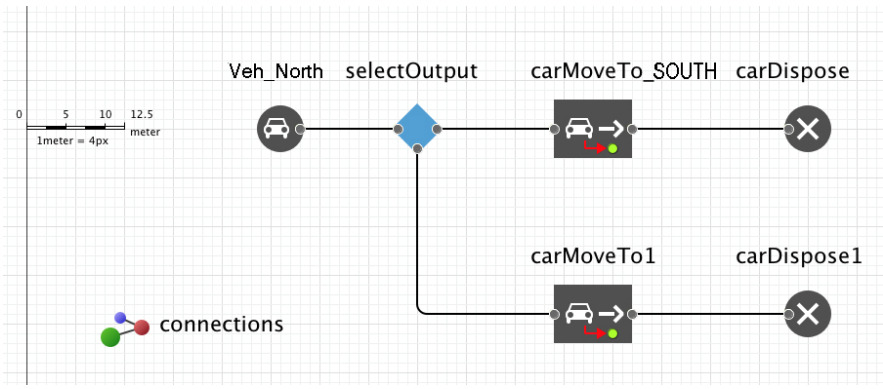


Figure 4.74. *The organigram featuring three new blocks*

Click on the new block **CAR MOVE TO** that you have just added in order to display its properties.

Rename it “carMoveTO_EAST” and in **ROAD** select road no. 2.

Select the **SELECT OUTPUT** block and in properties, enter 0.6 for the **PROBABILITY** field and tick **END OF BACKWARD LANE** for **DESTINATION.**

The steps that you have just taken will direct 60% of the vehicles towards the south and 40% towards the east.

Save your model (menu **FILE – SAVE**).

NOTE. – It is not necessary for you to change the name of different blocks. However, doing so will make it easier to understand and re-read previously defined operations.

4.6.2.6. *Test no. 2 of the model simulation*

In the **MODEL** menu, select **RUN** or click on the **RUN** icon in the horizontal toolbar.

Click on the **RUN** button to launch the simulation. You should now see vehicles traveling south and east from the north.

Figure 4.75. *The model in simulation mode featuring four vehicles (green, blue, cyan, green) traveling south, three (green, blue, magenta) traveling east and one (red) arriving from the north. For a color version of this figure, see www.iste.co.uk/reveillac/modeling2.zip*

When configuring the blocks, pay attention to the direction of traffic from its source.

In the previous example, vehicles were traveling in a southbound direction from the north (source), meaning that the direction was forward (**END OF FORWARD LANE**) in the route chosen for road no. 1 and no. 2. However, when vehicles turned left at the intersection, they traveled along road no. 2, which was designed to travel in a westbound direction, and they were therefore traveling in the opposite direction from the route, meaning that the direction was backwards (**END OF BACKWARD LANE**).

4.6.2.7. *Finalizing your model*

To finish this short example, we will add two vehicle sources, one from the east and one from the south. We will also create organigrams for traffic management following Figure 4.67 and relaunch the simulation before switching to a 3D simulation and an analysis of the results.

Start by creating two more organigrams with the same properties as those shown in Table 4.1.

Block/ Properties	Organigram 1	Organigram 2
CAR SOURCE		
NAME	"Veh_SOUTH"	"Veh_EAST"
ARRIVALS DEFINED BY	RATE	RATE
ARRIVAL RATE	900 per hour	600 per hour
ROAD	Street no.1 SOUTH	Street no. 2
ENTERS	BACKWARD LANE	FORWARD LANE
SELECT OUTPUT		
PROBABILITY	0.5	0.333
CAR MOVE TO		
NAME	"carMoveTo_NORTH"	"carMoveTo_SOUTH_2"*
ROAD	Street no.1 NORTH	Street no.1 SOUTH
DESTINATION	END OF BACKWARD LANE	END OF FORWARD LANE
CAR MOVE TO		
NAME	"carMoveTo_EAST_2"*	"carMoveTo_NORTH_2"

ROAD	Street no. 2	Street no. 1 NORTH
DESTINATION	END OF BACKWARD LANE	END OF BACKWARD LANE
CAR DISPOSE		
NAME	“carDispose2”	“carDispose4”
CAR DISPOSE		
NAME	“carDispose3”	“carDispose5”
**The same block name cannot be used more than once*		

Table 4.1. *Properties of the blocks for the two new organigrams*

When finished, you should have three organigrams similar to those in Figure 4.76.

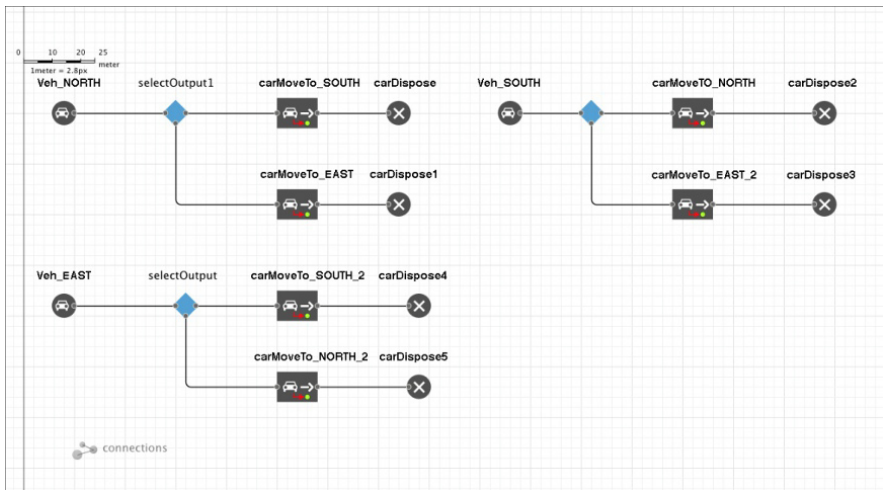


Figure 4.76. *The three-vehicle management organigrams within our model*

4.6.2.8. *Test no. 3 of the model simulation*

When you launch the model simulation, you should see vehicles traveling from the north, the south and the east. When they reach the intersection they will travel in one of the possible directions, depending on the probabilities entered.

Figure 4.77. *Arriving from different sources, the vehicles will travel in random directions depending on the probabilities entered when the properties were configured. For a color version of this figure, see www.iste.co.uk/reveillac/modeling2.zip*

4.6.2.9. *Switching to a 3D simulation*

With Anylogic, it is possible to generate a 3D simulation of your model.

In the **PALETTE** window, select the **PRESENTATION** library in the vertical toolbar and drag a **3D WINDOW** block under your model.

Select the **ROAD TRAFFIC LIBRARY**, drag and drop a **CAR TYPE** block to the left of your **3D WINDOW** block.

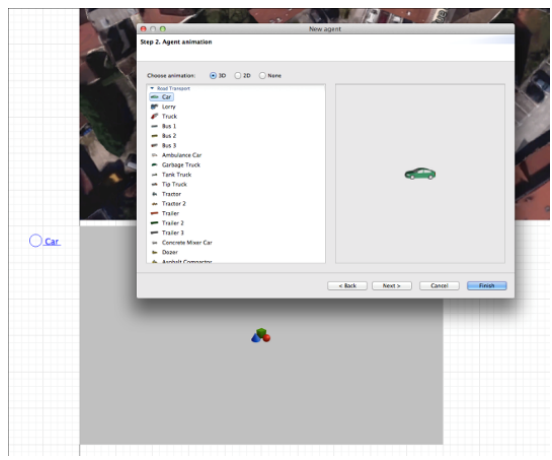


Figure 4.78. *The CAR TYPE block and the NEW AGENT dialog box with CAR selected*

A dialog box – **NEW AGENT** – will open. Click on the **NEXT** button, verify the vehicle model (**CAR**), click on **NEXT** and then **FINISH**.

A window (**CAR**) and its tab will open next to **MAIN**, showing the vehicle that you have selected.

In this window you will be able to modify the size of the vehicle using the scale indicator (see section 4.5.2.2).

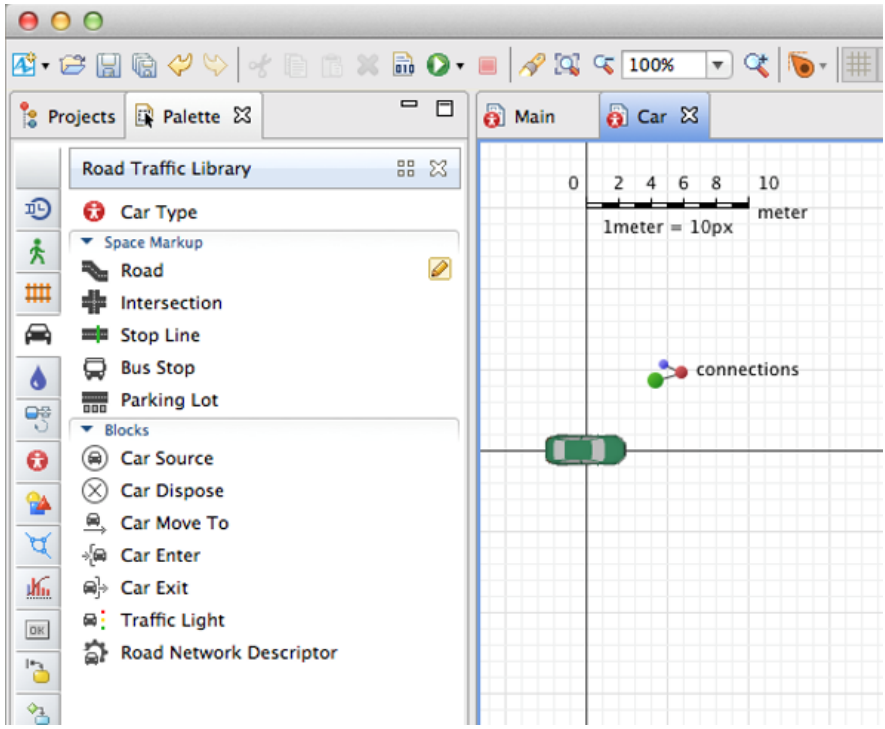


Figure 4.79. *The new tab CAR next to the MAIN tab, containing the vehicle and its scale indicator*

Return to the **MAIN** tab, select each of the vehicle source blocks in turn, “Veh_NORD”, “Veh_SUD” and “Veh_EAST” for your three organigrams. For each of them, enter the value **CAR** in the **NEW CAR** field, within the **PROPERTIES** window, in the zone **CAR**.

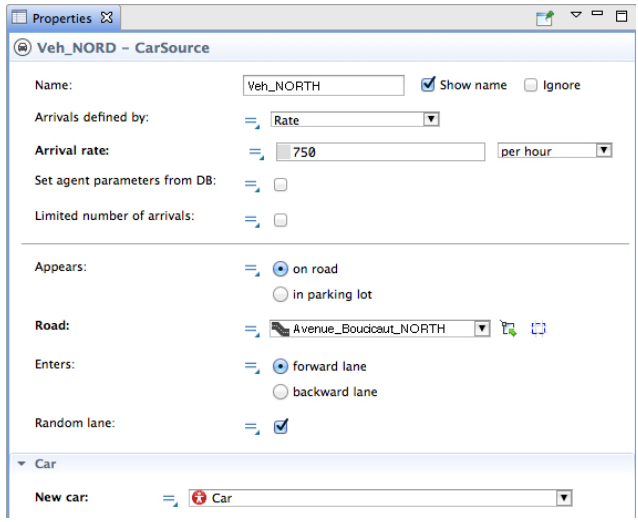


Figure 4.80. *The NEW CAR field (on the bottom) containing the value CAR, in the properties for the "Veh_NORD" source*

4.6.2.10. *Final test of the model simulation*

Launch the simulator and click on the **RUN** button. In the simulation window, click on the **NAVIGATE TO VIEW AREA** icon and select **[WINDOWS3D]**.

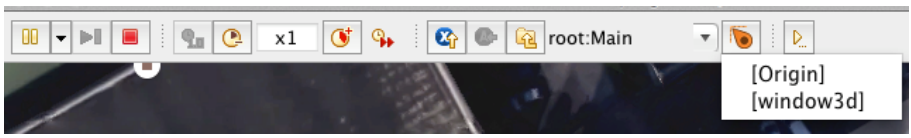


Figure 4.81. *The simulator toolbar and the NAVIGATE TO VIEW AREA icon, as well as the [WINDOWS3D] option (on the right)*

A 3D model should appear and your simulation should start.

In this window, there are several options available for navigation and movement:

– Mouse scroll: zoom in and out;

– ALT + click drag-and-drop: rotate the background map right or left;

– Click + drag-and-drop: up-down-right-left translation.

4.6.3. *A last word on AnyLogic*

As I pointed out earlier, Anylogic is a powerful, highly sophisticated simulator, which has been shown to be adaptable to the majority of situations, whether for road traffic management or in other sectors.

I could have expanded our example by including traffic lights, public transport vehicles, parking, the management of pedestrians, a detailed analysis of the density and flow of traffic in the form of tables, graphs, etc.

However, I will not go any further at this point. The help provided with the program is extensive, so feel free to consult the tutorials, videos and the various examples that are available, as well as the editor's website (**HELP** menu, then **WELCOME** or **HELP**, then **EXAMPLE MODELS**).

4.7. Conclusion

We will end our short overview of traffic simulators at this point.

I would suggest that you take some time to search for other tools online using your preferred search engine.

Here are a few links[9] to get you started:

– sourceforge.net/projects/atsimu/: Traffic Simulation, a microscopic traffic simulator developed by Microsoft Visual C++;

– www.ctr.kth.se/mezzo.php: Mezzo: A mesoscopic traffic simulator;

– sourceforge.net/projects/tsignals/: Traffic Signals, a smart simulator for four-lane intersections;

– sourceforge.net/projects/sumotrafficc/: SUMO Traffic Creator, a road network simulator featuring road maps, among other features.

9 This link was active at the time of writing. Should any problems arise, use your preferred search engine.

Glossary

Affine function: a function in the form of $y = ax + b$. The variable a is called the leading coefficient and the variable b, y-intercept. A linear function is a straight line. When it goes through the origin, in this particular case (y-intercept null), we then get a linear function ($y = ax$).

Analytical resolution: in this type of problem solving, the approach to the solution is based on a mathematical procedure that provides precise and rapid result(s). In parallel with analytical resolution, we can choose a graphic solution. In linear programming, the simplex method is a type of analytical resolution.

Branch and bound: a method that consists of finding the optimum solution to a problem of combinatorial optimization. It is built around the concept of separation (branch) that carves the group of solutions into subsets of a smaller size and optimistic assessment in increasing (bound) these same subsets.

BRIC (Brazil, Russia, India and China): acronym designating the four principal developing countries.

Canonical form (or standard form): form of a problem in linear programming in which the constraints are expressed by inequations.

CAPM (computer-aided production management): software dedicated to managing all of the activities related to production in a business. Here, we can find, in the form of modules, the management of orders, the management of articles, the management of resources, the management of bills or materials and ranges of products, management of planning de fabrication, the management of purchases, etc.

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First Edition. Jean-Michel Réveillac.

Cardinality: a pair of values attached to a relation in the entity-relationship model (relational model). For a relationship (or association) between two entities, two pairs must be specified. The cardinalities express the number of times that the occurrence of an entity can be taken into account in the relationship, at minimum or maximum. There are four typical cardinality pairs: (*0*, *1*), (*1*, *1*), (*0*, *n*) and (1, *n*), *n* being the equivalent of several.

Concentration: also known as density. For a traffic model, this is the number of vehicles present on a given length of a route at a defined time.

Constraint: factor or condition that an optimization problem must satisfy.

CONTRAM: mesoscopic model of road traffic.

CPM (critical path method): method for calculating a critical path on a graph for planning tasks.

Decision-making aid: a group of techniques based on probability theory, graph theory or even operational research. They offer the opportunity for a human actor to opt for the best possible solution when faced with problems that are mainly industrial, financial or other.

Density: for road traffic, density is defined as the number of vehicles per unit length of the roadway.

Deterministic algorithm: an algorithm that carries out a predefined process in order to resolve a problem.

Dual: in linear programming, the initial problem, called "primal", is associated with another linear problem known as a "dual" problem. In some ways, the "dual" is the symmetrical to the "primal".

DynaMIT: mesoscopic model of road traffic.

Economic function (or cost function): function to be optimized in the context of linear programming.

Fastlane: mesoscopic model of road traffic.

Flow: for road traffic, flow is the number of vehicles passing a reference point per unit of time, vehicles per hour.

GRH (Gazis, Herman and Rothery): microscopic model of road traffic.

Heuristic: refers to a method that proceeds by successive approaches progressively eliminating the alternatives to keep only a limited group of solutions leaning toward optimality.

Hybrid: refers to a method of traffic simulation model combining microscopic and macroscopic modes with the possibility, among others, to go from one to the other via a simple change in scale.

ITS (Intelligent Transportation Systems): application of NICT designed for transportation.

Kirchhoff's Law: also known as the "nodal rule". This is a law that shows the conservation of energy in an electrical circuit. The sum of the intensity of the currents that enter into a node is equal to the sum of the intensities of the currents that come out of it. By extension, this law can be found in operational research, among other things, with the management of floats.

Linear function: see *affine function*.

LWR (Lighthill, Witham, Richards): macroscopic traffic model known as an equilibrium model.

Macroscopic: simulation mode within a traffic model. In this case, the flow approach of the network is global and involves large areas.

Maximization: refers to a problem of optimization when its objective must lead toward a maximum.

Mesoscopic: intermediate traffic simulation mode between microscopic and macroscopic.

Microscopic: simulation mode within a traffic model considering each of the vehicles and their interactions. This mode works on zones with small dimensions (crossings, crossroads, small groups of streets).

Minimization: refers to an optimization problem when its goal must must lead toward a minimum.

MPM (métra potential method): a method invented by Bernard Roy in 1958. It allows for the representation and optimization of a project in the form of a network-type diagram showing, among other things, the intertask dependencies while reducing delays and by constructing a critical path. With MPM, the tasks are symbolized by nodes (vertices) unlike the PERT method.

MST (minimum spanning tree): see *MWST*.

MWST (minimum weight spanning tree): a tree that connects all of the vertices of a graph and where sum of the weight of each one of its edges is minimal.

Normal distribution: also known as "Gaussian law" or "Gauss Laplace distribution". This is the law of probability that is most often used in statistics. Its curve is known as a "bell curve" due to its shape. It has two parameters: expectancy and a real number that makes it possible to calculate the probabilities of a group of random continuous variables.

Objective: this is a shortcut for talking about objective function. This function is the principal criterion for determining the solution of a mathematical optimization problem.

ODM (origin/destination model): macroscopic model of road traffic.

ODS (open document spreadsheet): file extension and open document format dedicated to spreadsheets based on the ODF (Open Document Format for Office Applications) standard. This format is used, in particular, by "Calc", the spreadsheet from the OpenOffice Suite.

OOP (object-oriented programming): computerized programming mode created in the 1960s by O.J. Dahl and K. Nygaard, then continued by A. Kay. It is built around objects that are software modules interacting with each other and representing an idea, a concept or an existing entity in the physical world. Numerous languages such as Java, C++, PHP and Ada using this programming mode. The concept of an object is also present within SE (Software Environments – Microsoft Visual Studio, Netbeans, etc.) in certain modeling tools (UML, DBDesigner, etc.) and in distributed buses (Corba, Pyro, RMI, etc.).

PEP (program evaluation procedure): planning method used by the United States Air Force.

PERT (program evaluation and review technology or **program evaluation research task):** project planning method developed by Booz, Allen and Hamilton, near the end of the 1950s, at the request of the Special Projects Office of the United States Navy. It makes it possible to create a connected, directed and weighted graph, where each of the tasks is represented by an arc that joins two vertices. It optimizes the project while taking into account the dependency constraints in order to determine the critical path and tasks.

Pivot: also known as the “Gauss Pivot”. The pivot is attached to the method of the same name (also called the “Gauss–Jordan elimination”). This is an algorithm that determines the solutions of a system of linear equations.

Primal: refers to the initial problem in linear programming.

RBDMS (relational database management system): database management system that manages the relationships forming the constraints that guarantee the referential integrity of the data.

Relation: equivalent to an association between two entities in a relational model. Link established between two tables within an RBDMS.

Relational algebra: this is the logical and mathematical support on which the relational model is based. It offers a group of elementary operations for creating new relations.

Retroactive planning: also known as “feedback scheduling”. This is an inverted planning method that conceives of a project starting with the end date and then go back toward the beginning. This method may be used when the end date of the project is determined in advance and mandatory.

SEP (Separation and Evaluation Procedure): see *Branch and bound*.

VBA (Visual Basic Application): implementation of the Microsoft Visual Basic language within Microsoft Office applications. Some applications such as WordPerfect, SolidWorks or AutoCAD also integrate a part of this language.

VBE (Visual Basic Editor): editing and development tool in the VBA language. This can also be an acronym for Visual Basic for Excel.

WBS (work breakdown structure): system of hierarchical breakdown of the tasks of a project.

Conclusion

In this second volume, you have been introduced to various possible ways of using spreadsheets as well as the standard operations and features of a project manager and the different processes available for managing vehicle flow within road networks.

Since the arrival of Visicalc[1] and Multiplan[2], the pioneers of electronic spreadsheets, spreadsheets have undergone a number of evolutions, bringing with them new features, but the fundamental principles remain the same. If you are wondering why this might be, the appearance on the market of the spreadsheet Improv[3] might provide us with some answers.

Improv wanted to introduce a new way of structuring data alongside functional evolution (multi-level cells for example), but it was a total commercial failure. Only specialists were impressed and aware of its real potential.

For the majority of users, spreadsheets are complex tools in terms of understanding and functional logic, and it therefore seems difficult to change their design. Microsoft were fully aware of this, and decided to import Multiplan into a new product, Excel[4], which has since gone on to be the most popular spreadsheet on the market.

Other editors didn't lose any time and created equivalent products.

1 The first genuine spreadsheet was created by Bricklin D., Frankston B. and Fylstra D. in May 1979.
2 Microsoft spreadsheet from 1982.
3 Spreadsheet developed by Lotus in 1991 for the platform NeXTSTEP, then for Microsoft Windows in 1993.
4 Spreadsheet from 1984. One of the references for spreadsheets today, it is part of the Microsoft Office Suite.

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Although the versions are constantly changing and users are increasingly well-informed, it should be pointed out that the majority of spreadsheets continue to make errors in their calculations (around 3% of cells[5]). Even if this rate seems to be decreasing as editors pay close attention to fundamental bugs, introduce corrective measures and work on the design of their products, new features appear and these lead to new issues.

Often, these errors are due to the users themselves. In some ways this is similar to statistics in general: depending on how they are interpreted, you can make them say whatever you like.

By now you will have understood that there is nothing revolutionary on the horizon for the future of spreadsheets. The existence of new rules, new alerts and better developed utilization logic, together with a deeper understanding of the features on the part of users will lead the way for the spreadsheets of tomorrow.

In terms of project managers, these are increasingly associated with human resources management tools, thus opening the door to an integration of tools concerning pay and financial applications such as the management of repayments. These are often linked to company management production which itself can form part of an internal Enterprise Resource Planning (ERP[6]) model.

The management of project funding is one of the features currently in vogue, along with the ability to intervene in planning using an internet browser.

The major evolutions with this type of software largely relate to the ever-present relationships with the information system by adding tools such as a messaging platform, the possibility of using the Lightweight Directory Access Protocol (LDAP[7]), connections with Electronic Document Management (EDM[8]), unique Single Sign-On (SSO[9]) authentication and links with datamarts[10].

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5 See the publications by CLEMONT M., *A scalable approach to spreadsheet evolution,* University of Klagenfurt, March 2003 and by PANKO R., *Spreadsheet research*.

6 Also designed in French under the acronym Progiciel de Gestion Intégré (PGI).

7 Protocol for questioning, modification and online directories based on TCP/IP. This has become the standard and includes a data model, a naming model, a security model and a replication model, designed for the directories. Its structure is based on an attributes-values node tree.

8 Electronic Document Management is also known as the Document Management System and forms part of the *workflow* which describes and formalizes the different stages of the journey for the management of data flow.

9 The aim of SSO is to centralise authentication in order to allow the user to access all available resources from their workstation and across the whole network.

10 Subset of a data warehouse.

This second volume only deals with certain subjects relating to the modelling and simulation of flows. I would invite the reader to consult and read Volume 3 of this work to learn more about the management of flows relating to transportation, warehousing, transport, security, checking, the evacuation of personnel, etc. You can also explore software such as ExtendSim, FlexSim or Thunderhead PathFinder.

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Internet links

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Graph theory and operational research

ELSEVIER: European journal of operational research *(in French)*, www.journals.elsevier.com/european-journal-of-operational-research/

INSA ROUEN: Graph theory and operational research *(in French)*, https://moodle.insa-rouen.fr/course/view.php?id=124

ROADEF: French society of operational research and decision aids *(in French)*, www.roadef.org/content/road/road.htm

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University of Metz: Modelling maximal flow problems *(in French)*, http://ensrotice.sciences.univ-metz.fr/module_avance_thg_voo6/co/modelflotmax.html

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GeoGebra: The calculating software for functions, geometry, algebra etc. Site for resources and downloads http://www.geogebra.org

GeoGebra: A tutorial written in English by Marc Renault http://webspace.ship.edu/msrenault/tutorial/

GeoGebra: New figures to see and make with GeoGebra *(in French)*, http://rdassonval.free.fr/geogebra/

Databases and relational algebra

University of Paris 8: Database, relational algebra *(in French)*, Rim Chaabane www.ai.univ-paris8.fr/~lysop/bd/seance5-ModeleRel-suite.pdf

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What is an SGBDR? *(in French)*, Fabien Celaia http://fadace.developpez.com/sql/coddsgbdr/

Tables, Pivot Tables and VBA with Microsoft Excel

Excel practice, free VBA tutorial *(in French)* www.excel-pratique.com/fr/vba.php

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Paris-Dauphine University: VBA initiation for Excel *(in French)*, Philippe Bernard www.master272.com/finance/GP_L3/docs/VBA.pdf

Towson University: Excel 2013: PivotTables and Macros, Pamela J. Taylor https://www.towson.edu/adminfinance/ots/trainingdoc/customguide/Excel2013/Excel %202013_PivotTables %20and %20Macros_studentFINAL.pdf

College of Business Administration, Kansas State University: Conducting Data Analysis Using a Pivot Table, Brian Kovar http://info.cba.ksu.edu/bkovar/PivotTableTutorial.pdf

Spreadsheets in Excel 2007 *(in French)* http://silkyroad.developpez.com/excel/tableau/

AgroParisTech: Using lists of data with Excel 2007 *(in French)*, Michel Cartereau www.agroparistech.fr/mmip/mc/bazar/envoi.php?nom_fichier=cours-listes-excel 2007.pdf

Flow simulation

ExtendSim, flow simulation software, editor's website www.extendsim.com

A download of the demo version of ExtendSim https://www.extendsim.com/prods_demo.html

FlexSim, flow simulation software, editor's website https://www.flexsim.com

Arena, flow simulation software, editor's website https://www.arenasimulation. com

Witness, flow simulation software, editor's website www.lanner.com

SimWalk, simulation software for pedestrian flow, editor's website www.simwalk.com

PTV Group, PTV Vissim, traffic simulation software, editor's website www.ptvgroup.com

TSS, Aimsun, traffic simulation software, editor's website www.aimsun.com

Caliper, TransModeler, traffic simulation software, editor's website www.caliper.com/transmodeler/

AnyLogic, traffic simulation software, editor's website www.anylogic.com

Simio, flow simulation software, editor's website www.simio.com

Simul8, flow simulation software, editor's website www.simul8.com

SFPE, Society of Fire Protection http://www.sfpe-chapitre-francais.fr/ (French website) http://www.sfpe.org/ (American website)

Project management

Sciforma, project management software, editor's website www.sciforma.com

Visual Planning, project management software, editor's website http://www.visual-planning.com

Microsoft Project, project management software, editor's website https://products.office.com/fr-fr/project/project-and-portfolio-management-software

GanttProject, project management software, editor's website www.ganttproject.biz

The Wikipedia page devoted to project management software, including an enormous list of applications *(in French)*, http://fr.wikipedia.org/wiki/Logiciel_de_gestion_de_projets

Appendices

Appendix 1

Installing the Solver

A1.1. Introduction

Chapter 1 makes several references to the "Solver" tool in Microsoft Excel. By default, this feature is not always installed and will therefore not appear in the menus, the toolbar icons or the icons featured within the different groups in the ribbon.

Below you will find the steps required for proper installation depending on the different version of Microsoft Excel for Microsoft Windows or for Apple Mac OSX.

A.1.2. Microsoft Excel 1997, 2002 and 2003 for Windows

In the TOOLS menu, select ADD-INS.

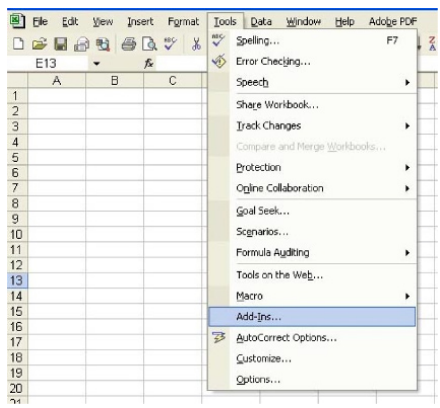

Figure A1.1. *The ADD-INS option in the TOOLS menu*

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First Edition. Jean-Michel Réveillac.

A dialog box will open. Tick “Add-ins…” and click on the OK button.

Figure A1.2. *The list of add-ins with the “Solver Add-In” to be ticked*

In order to locate the solver click on the TOOLS menu and select SOLVER.

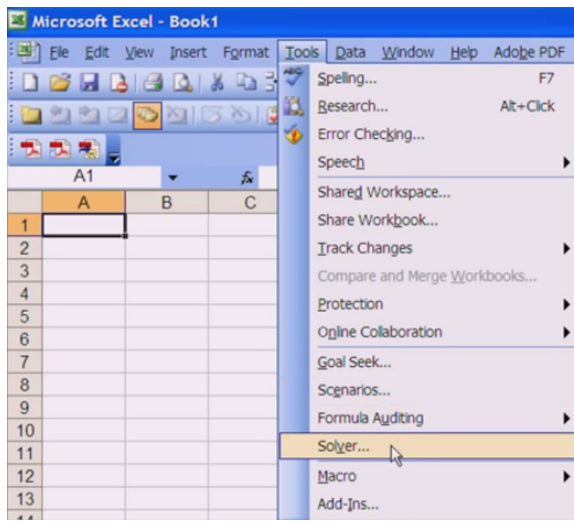

Figure A1.3. *The option for opening the SOLVER from the TOOLS menu*

A1.3. Microsoft Excel 2007–2010 for Windows

For Microsoft Excel 2007, click on the Office button (top left).

Figure A1.4. *Top left – the Office button in Excel 2007*

In the window that opens click on the EXCEL OPTIONS button (bottom right, next to the QUIT EXCEL button).

For Microsoft Excel 2010, open the FILE menu and select OPTIONS. A dialog box will open. Select "Adds-Ins" in the list on the left.

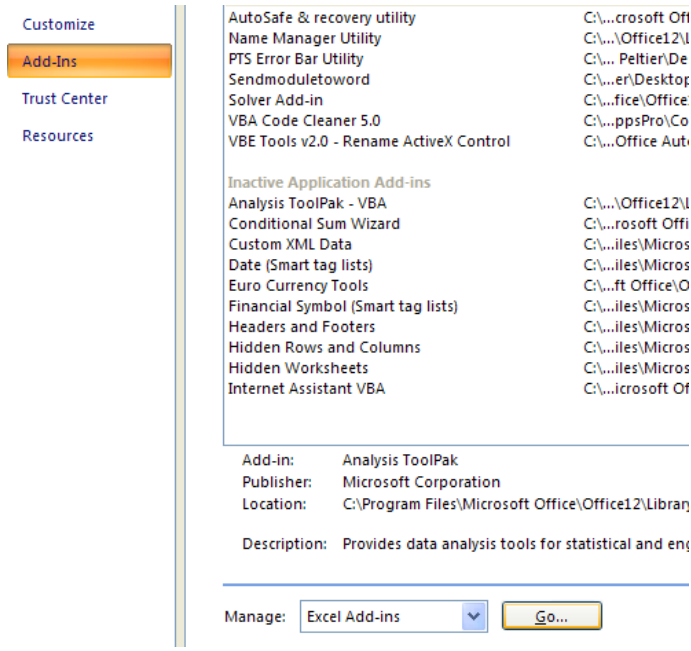

Figure A1.5. *The Excel add-ins featuring the drop-down list MANAGE (bottom right) and the GO button*

Across from the “Manage” field (at the bottom), select “Excel Add-Ins” in the drop-down menu, then click on the GO button.

A dialog box for add-ins will open. Select “Solver Add-In” and click on the OK button.

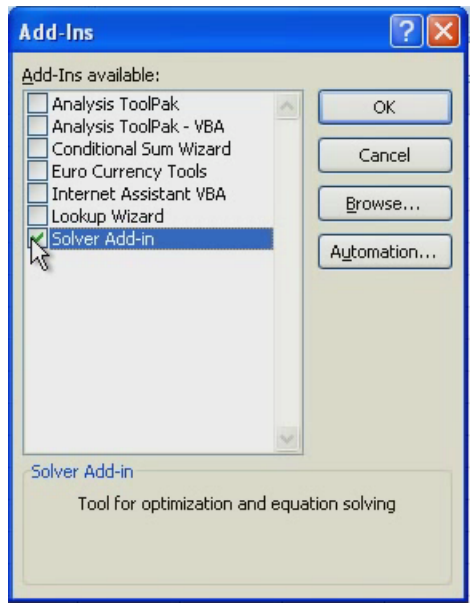

Figure A1.6. *The dialog box displaying the available add-ins*

The solver is the last tool available (on the right) in the ribbon beneath the DATA tab in the ANALYSIS group.

A1.4. Microsoft Excel 2013 for Windows

In the FILE menu, select OPTIONS in the vertical ribbon located on the left.

A dialog box will open. In the list on the left, select ADD-INS.

In the section on the right, you should see all of the available add-ins for Microsoft Office, including the one called “Solver Add-In”.

In the lower section, across from the field “Manage” (at the bottom), select “Excel Add-Ins” from the drop-down menu, then click on the GO button.

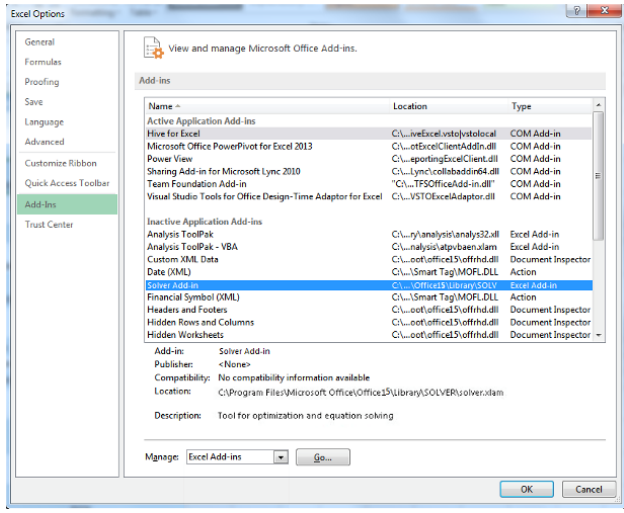

Figure A1.7. *The dialog box showing the list of available add-ins for Microsoft Excel 2013. At the bottom, we can see the "Manage" field along with its drop-down menu and GO button*

A new dialog box, "Add-Ins" should open, showing a list of the available add-ins.

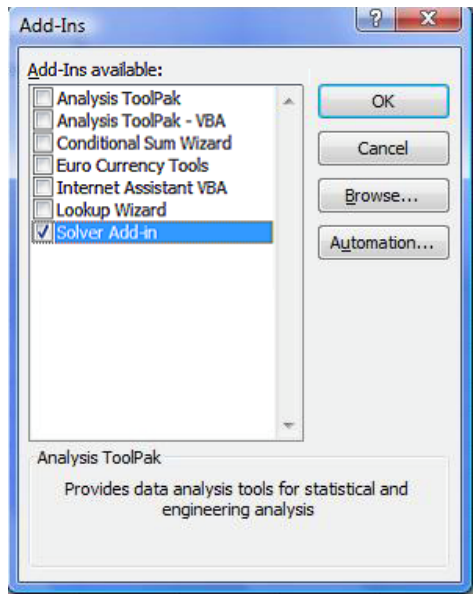

Figure A1.8. *The "Add-Ins" dialog box*

Select “Solver Add-In” and click on the OK button.

COMMENT A1.1.– If “Solver Add-In” does not appear on the list, click on the BROWSE button. In the file explorer window that opens, go to “Programs\Microsoft Office\Office15\Library\SOLVER”, select the file “SOLVER.XLAM” then click on the OK button.

To locate the solver, click on the DATA menu in the ribbon on the right in the ANALYSIS group and you should see the solver icon.

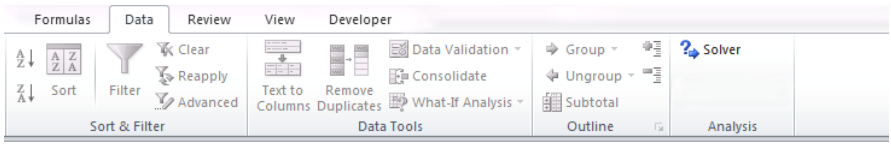

Figure A1.9. *The ribbon in the DATA menu including the solver icon on the right*

A1.5. Microsoft Excel for Mac 2008-2011

In the TOOLS menu, select ADD-INS.

In the “Add-ins” dialog box that appears, select “Solver.Xlam” and click on the OK button.

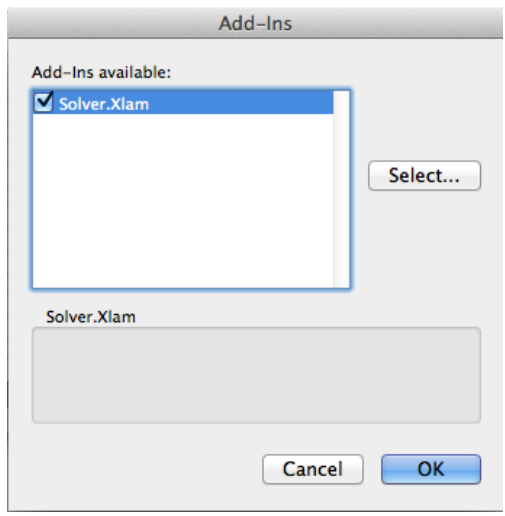

Figure A1.10. *The dialog box for installing the solver add-in*

COMMENT A1.2. – If "Solver.Xlam" does not appear in the list "Available add-ins", click on the SELECT button, open "Applications", and search in the folder "Microsoft Office 2008" or "Microsoft Office 2011" then the sub-folder "Office" then "Add-ins" and select "Solver.xlam". Click on the OPEN button and it should appear in the list of the "Add-ins" dialog box.

To open the solver from a spreadsheet, go to the TOOLS menu and select SOLVER...

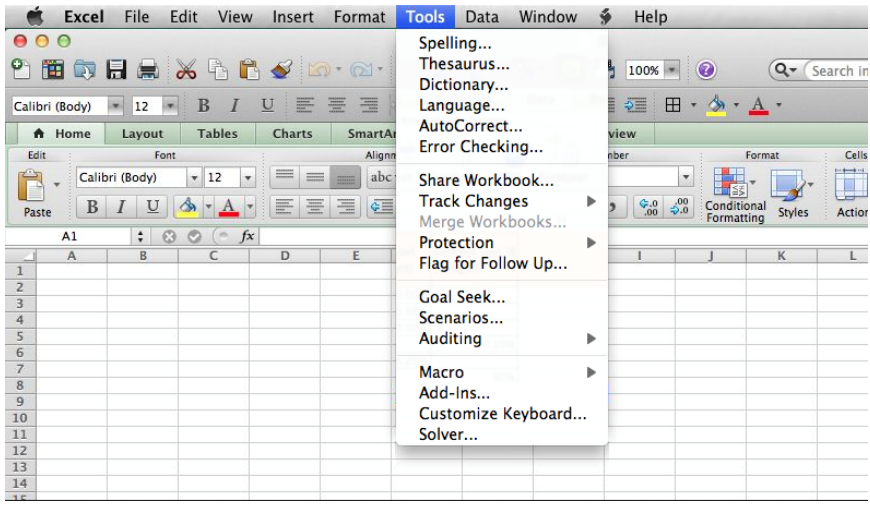

Figure A1.11. *The TOOLS menu and the option SOLVER… (last option on the list)*

Appendix 2

Installing the Java Development Kit

A2.1. Why Java?

Presented in May 1995 and developed by J. Gosling and P. Naughton of Sun Microsystems, *Java* is an object-oriented programming language. It is now owned by Oracle which bought Sun in 2009.

Java's slogan is WORA "*Write once, run anywhere*".

By now, you will have understood that one of the main advantages of Java is its *portability*. You take your source code and you compile it once and it can then be used on any platform (Microsoft Windows, Linux, OSX, etc.)

Another important advantage is the fact that it is free.

When you download Java, you are able to access the Java Runtime Environment (JRE). It is made up of Java Virtual Machine (JVM), standard classes and Java libraries.

JVM interprets the Java bytecode, controls how it interacts with the operating system and manages memory.

The JVE relates to the running of the Java software and makes it possible to run a Java application.

Java Development Kit (JDK) is the development kit for the Java language. It incorporates, among others, the compilation tools and the debugger.

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JDK contains JRE in order to be able to test the applications developed.

A2.2. Downloading

Download the Java Standard Edition (SE) development kit (JDK) at: www.oracle.com/technetwork/java/javase/downloads/index.html. Be sure to select the appropriate version for your operating system.

COMMENT A2.1.– Please note that this address is subject to change. Should this happen, use a search engine to search for JDK.

A2.3. Testing the presence of the JDK compiler

Install JDK. Once it has been installed, open your system's command menu.

With the OSX platform, use the application Terminal, located in the "Applications/Utilities" folder.

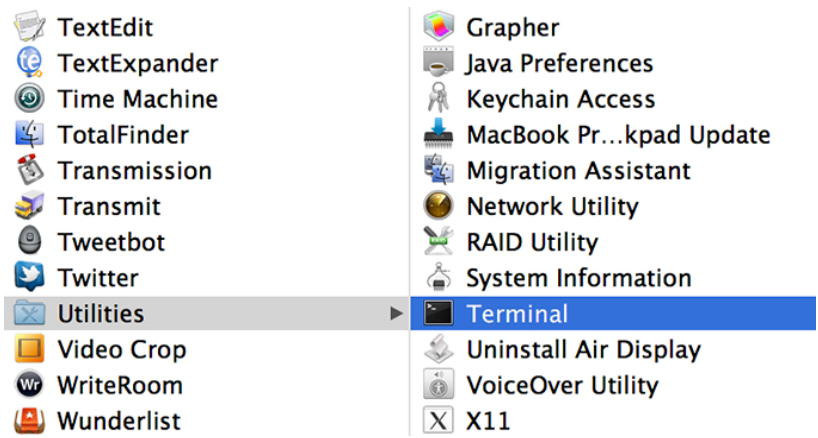

Figure A2.1. *The sub-folder "Utilities", located in the "Applications" folder in OSX. Note the application "Terminal"*

Below Microsoft Windows 7, enter "cmd" in "Search programs and files" from the **START** menu (circle featuring the Microsoft Windows logo), at the bottom left, then confirm by pressing ENTER.

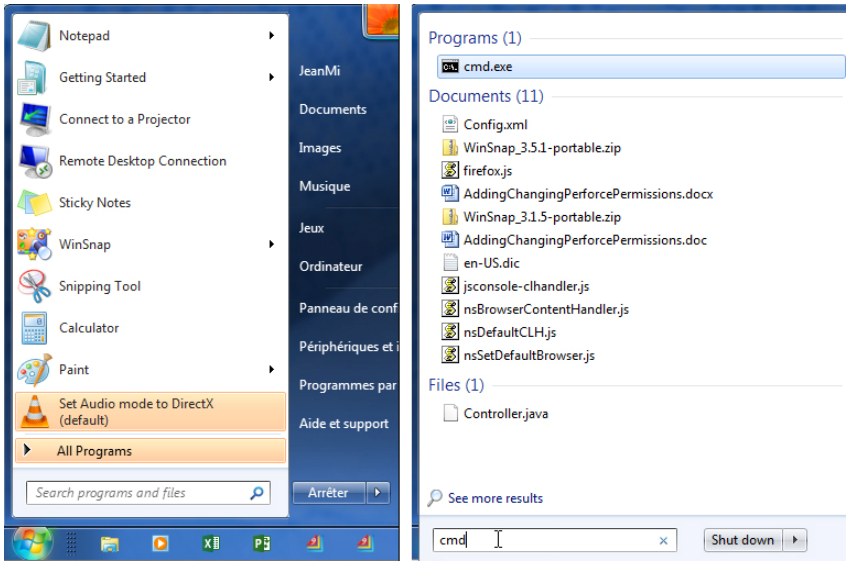

Figure A2.2. *The field "Search programs and files" (on the left) and inputting "cmd" in the same field (on the right)*

In Microsoft Windows XP, from the **START** menu, at the bottom left, go to "Run", type "cmd" in the **OPEN** field in the **RUN** dialog box that will open, then click on the **OK** button.

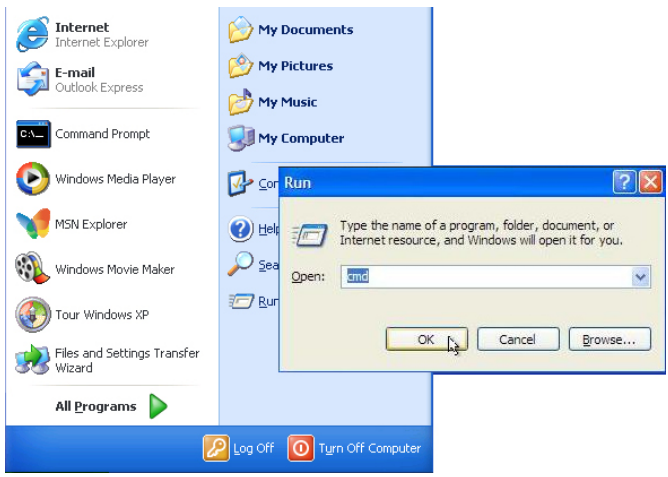

Figure A2.3. *The "Run" option from "All programs" and the RUN dialog box featuring the field OPEN containing "cmd"*

You can also access the "Command Prompt" from "All programs" in the "Accessories" folder.

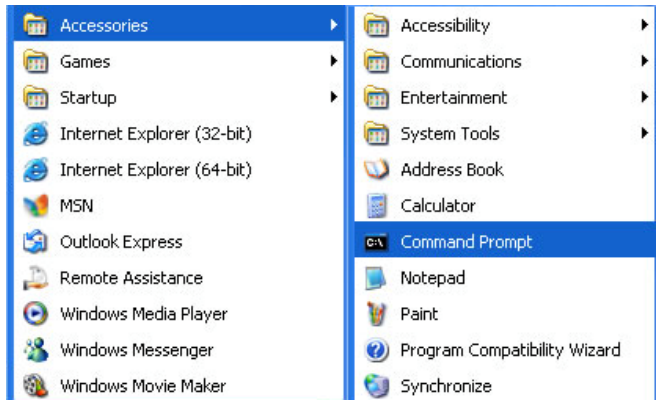

Figure A2.4. *The "command prompt" option in the "Accessories" folder in Microsoft Windows XP*

COMMENT A2.2.– In Microsoft Windows 8, you can access the RUN command by holding down the Windows button and pressing "R".

Once your command menu window is displayed, enter "`javac`" followed by ENTER (open the java compiler). A list of commands for use should appear.

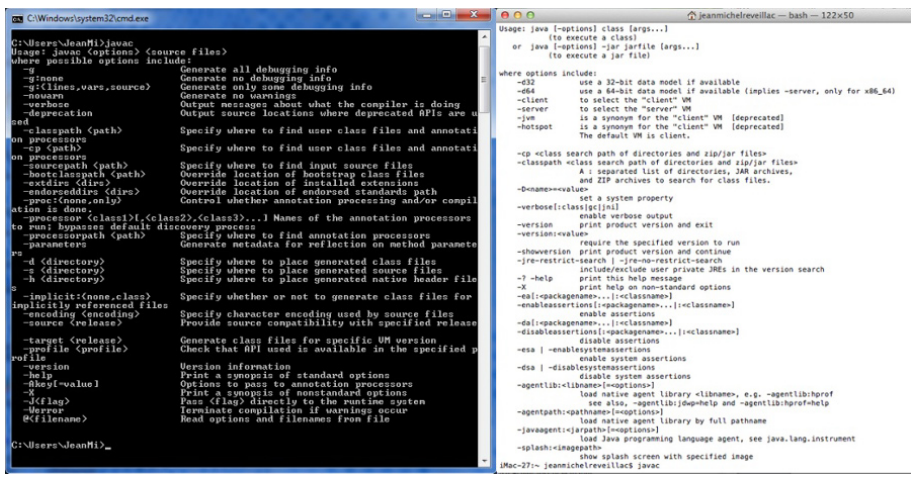

Figure A2.5. *The command list for use with "javac" from the Microsoft Windows command menu (on the left) and from the OSX Terminal (on the right)*

With OSX, you should not encounter any problems.

With Microsoft Windows, if this list doesn't appear and a message saying something along the lines of "*javac has not been recognized as an internal command…",* is displayed, this will be because you have forgotten the environment variable "*path*".

A2.4. Creating the environment variable

Here is the procedure to follow for resolving this issue:

– go to the Java installation folder, for example: *"C:\ProgramFiles\Java"*;

– open the folder of your JDK, for example *"jdk1.8.0_91"*;

– then open the folder *"bin"*;

– copy the access path for this folder, for example: *"C:\ ProgramFiles\Java\jdk1.8.0_91\bin"*;

– right click on your work post, then select **PROPERTIES**;

COMMENT A2.3.– It is also possible to access the system properties via the configuration by selecting **SYSTEM AND SECURITY**, then **SYSTEM** (Microsoft Windows 7) or **SYSTEM**, then the **ADVANCE** tab (Microsoft Windows XP).

– select ADVANCED SYSTEM PARAMETERS then click on the ENVIRONMENT VARIABLE button;

– select the variable "*Path*" in the list of variable users if it is there, and click on the **MODIFY** button. Otherwise, click on the **NEW** button and give it the name "*Path*";

– in the **VARIABLE VALUE** field, if a set of values is already present, add an "**;**" (semi-colon) at the end, then past the path that you have previously copied. Otherwise simply paste the copied path;

– click on the **OK** button to close each of the windows then finish by closing the properties window;

– your `"javac"` compiler should now be operational.

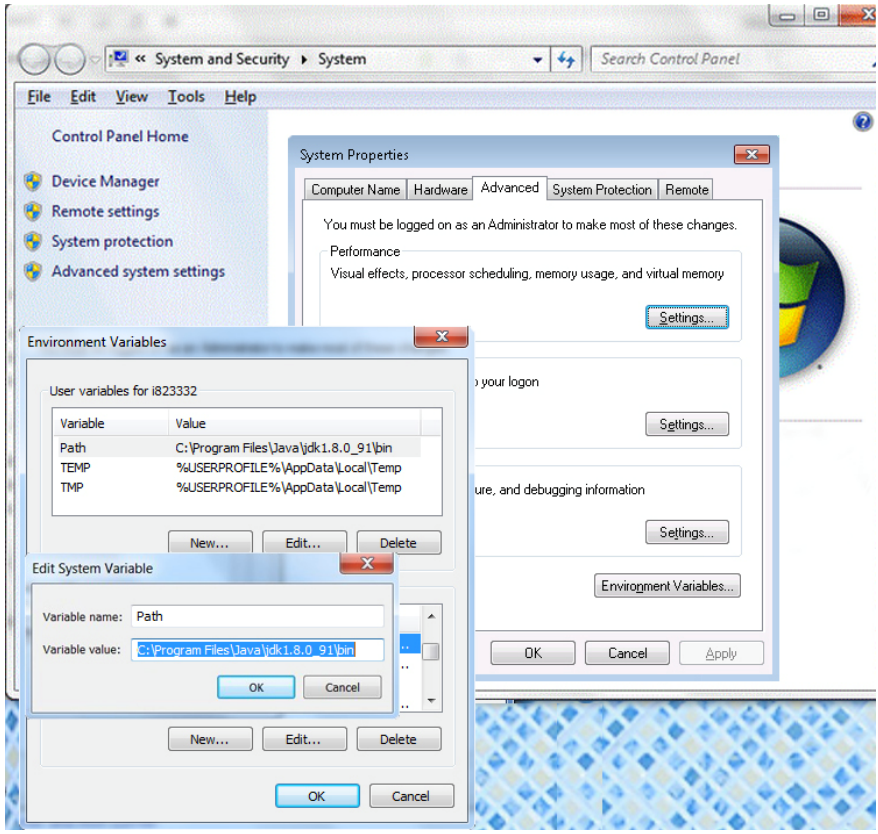

Figure A2.6. *From the properties of the work post we can see all of the windows for accessing the environment variable "Path" (Microsoft Windows 7)*

COMMENT A2.4.– In order to take into account the modifications relating to the environment variable, you will need to close and relaunch the command menu window.

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