Dieter Jacob / Clemens Müller

Estimating in Heavy Construction

Roads, Bridges, Tunnels, Foundations

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With a foreword of
Prof. Dr. Herbert Einstein,
Massachusetts Institute of Technology

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Foreword

There is no up-to-date English language textbook on heavy construction calculation/estimation, in contrast to building construction. This may be because this type of construction often involves heavy construction machinery from Germany and Asian countries. Therefore, I appreciate that such a textbook for contractors as well as clients has been provided.

This book can be used for US heavy construction, as well as heavy construction in Asia and developing countries. The examples are calculated in euros and can easily be changed into USD. The examples have to be adapted to the local/regional conditions with regard to wages and material costs. The sales tax/value added tax as used also needs to be adapted.

The book provides a good basis for estimation because all important cost categories are considered. The risks of different construction contracts are systematically evaluated with regard to risk distribution between owner and contractor. Specific risks, for instance for joint ventures, are also considered. A systematic scheme for the calculation of interim interest is provided as well.

The book differentiates between time-dependent and time-independent costs. This allows one to easily calculate the costs caused by delays. The initial strategy part of the book considers the effect of different levels of capacity utilization and the cost/profit consequences. The calculation/estimation is not presented as a deterministic process, but the book shows how this depends on strategic considerations, subjective factors and stochastic characteristics. The book also demonstrates the application of cost estimating software.

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Preface

In contrast to building construction, there are only a few available English books on estimating in heavy construction projects, such as roads, bridges and specialized foundation engineering works for buildings. This book is based on our German estimating book, in which we have collected German examples. These real projects can also be applied to the international market.

The estimating is based on specific construction methods which are dependent on the boundary conditions, the machinery available and the quality and training of personnel.

Be aware that estimating is always a stochastic process and cannot deliver a deterministic result. Reliable estimating is not only important for a contractor but also for a professional client who wants to have a rough overview of his cost situation, especially in civil engineering and underground construction. This is expensive, complicated work and one cannot simply measure square or cubic meters of living space as in standardized building engineering. One only has to think of related significant cost overruns in a few recent large-scale projects to understand the need for a publication written exclusively for heavy construction estimating.

We would especially like to thank all contributing heavy contractors such as Strabag Großprojekte GmbH, VINCI, Heijmans Oevermann GmbH, BAUER AG and Matthäi Bauunternehmen GmbH & Co. KG for their support.

Freiberg, September 2016 — Dieter Jacob, Clemens Müller (Editors)

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List of Abbreviations

acc.	according
approx.	approximately
av.	average
AW	average wage
BIM	Building Information Modelling
BOT	build, operate, transfer
BR	boring rate
C	concrete
CA	compressed air
CAD	computer-aided design
calc.	calculation
CAPM	capital asset pricing model
Cf.	compare
contr	contractor
Dia.	diameter
div.	division
dist.	distance
DW	diaphragm wall
ea.	each
EDP	electronic data processing
e. g.	exempli gratia – for example
Empl.	employee
ER	employer
GMP	guaranteed maximum price
HPI	high-pressure injection
hol.	holiday
i. e.	id est – in other words
ID	Identity
IDC	indirect costs
ISO	International Organization for Standardization
ins.	insurance
JV	joint venture
LOC	letter of credit
MT	microtunnel
OCC	overhead construction costs

OP	order procurement
P	performance
PC	prime Costs
pos.	position
PPP	public-private partnership
proc.	procurement
pub.	published
QM	quality management
qty.	quantity
QU	quantity unit
RAP	risk and profit
resp.	respectively
RMS	risk management system
RN	record number
str.	strength
SUB	subcontractor
TBM	tunnel boring machine
tot.	total
TP	total price
TS	tunnel segment
UoM	unit of measurement
UP	unit price
VaN	value as new
VAR	value at risk
VAT	value added tax (sales tax)
WG	wage group
w/o	without

Selected terms to help international understanding

A	motorway
AG	incorporated company
B	federal highway
BAL	construction site equipment list
BGB	German Civil Code
BSt	rebar steel
DIN	German Institute for Standardization
e.V.	registered association

ERA	UCP: Uniform Customs and Practise for Documentory Credits
FGSV	Construction of the Road and Transportation Research Association
GmbH	Limited (Ltd.)
KonTrag	Control and Transparency for Areas in Business Act
RQ	standard cross section
RStO	Guidelines for the standardization of the superstructure
VOB	Public Construction Tendering and Contract Regulations

Units

a	anno
CD	calender days
cm	centimeter
CW	calender weeks
d	day
EUR	euro
g	gram
h	hour
KEUR	thousand euros
km	kilometer
kW	kilowatt
kWh	kilowatt hour
l	liter
m	meter
min.	minute
mm	millimeter
mo	month
pc	piece
Q	quarter
RM	running meter
t	tons
WD	working days
w/c	water/cement ratio

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1 Strategy and estimating

It is more important than ever to follow appropriate strategies to be competitive; even more so in difficult economic times. The implementation of the strategies must be supported by efficient management.

1.1 Sales and marketing strategies

There are three different core area strategies available for the contractor, which can also be combined:[1)]

– Niche strategy (specialization): In this strategy, the main task is the concentration on niche markets. The company focuses on a specific, narrowly defined industry segment. These niches can include, for example, a specific purchasing group, a specific part of the performance program, or a geographically defined market.
– Cost leadership: This strategy aims at being the cheapest provider on the market. A comprehensive cost advantage should be reached within the branch by means of this strategy. This requires, for example, cost-cutting measures, strict cost control, and minimization of costs in certain areas, such as service or marketing.
– Comprehensive services (differentiation): The goal of this strategy is to offer services, which differ greatly in quality and variety from the services offered by the competition. By achieving a unique position against the competition (i. e. unique services), it is possible to overcome the cost-cutting strategies of the competition.

It is questionable whether a typical construction company can aim to make its sales entirely in niches. One does certainly strive strategically to save a certain share of revenue from the intense price competition.

In many cases a price war cannot be avoided. Cost-effective competitiveness can only be achieved through rationalization, utilization of the learning effect, and skillful procurement management (of construction materials and subcontractor services).

Niche and cost leadership strategies are particularly practicable for providers of individual trades. The differentiation strategy, on the other hand, is closely bound to the market presence of system providers[2)]. Table 1.1 describes both forms according to characteristics such as size of the company, depth of production, price margin etc.

1) Cf. the three types of competitive strategies: Porter (1999), pp. 70–85. To the topic of EU-eastward expansion: Jacob/Mollenhauer (2002), pp. 52–72 to the operational strategies of the domestic market penetration and Birtel (2002), pp. 73–82 to the operational strategies of the opening of the construction markets in the accession countries.

2) For the characteristics of the system provider cf. BWI-Bau (2013) p. 158.

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Table 1.1 Characteristics of single trade and system providers[3)]

Characteristic	Single trade provider	System provider
Size of the company	Small and medium-sized enterprises	Medium-sized and large enterprises
Scope of operation	Regional and superregional	Superregional, international
Depth of production	High	Low
Price margin	Low to large	Middle
Range of services	Homogeneous	Heterogeneous
Service program	Single crafts	Complete solutions
Position in the market	(seldom) Awarded to subcontractors, or subcontractors themselves	General company, general contractor, project company, consortium leader
Indirect resource demands	Handcrafting, technical, economic, tax and legal know-how, innovation know-how, competence in problem solving	Moreover: coordination and organizational know-how; integration know-how

Not only is the definition of the strategy of practical relevance, but its execution is as well. Examples of the reduction or expansion of value added are provided in the construction business management working group, Schmalenbach-Gesellschaft[4)]. The balanced scorecard offers one possible instrument for the successful implementation of strategies in enterprises.[5)]

It is always important to know one's strengths and weaknesses. Which special benefits can one offer the customer in comparison to the competition? Where are the central needs of the market? Ultimately the question arises, where one can stand reasonably in regard to dependence on customer benefits and central market needs.

3) Stuhr (2007), p. 57.

4) Cf. optimizing the results with FOKUS and Reduction of real net output Adenauer (2005) pp. 25–36 and extension of added value in a mid-sized company Schmieg (2005), pp. 37–48.

5) Cf. construction-related application balanced scorecard Stuhr (2009), pp. 14–16.

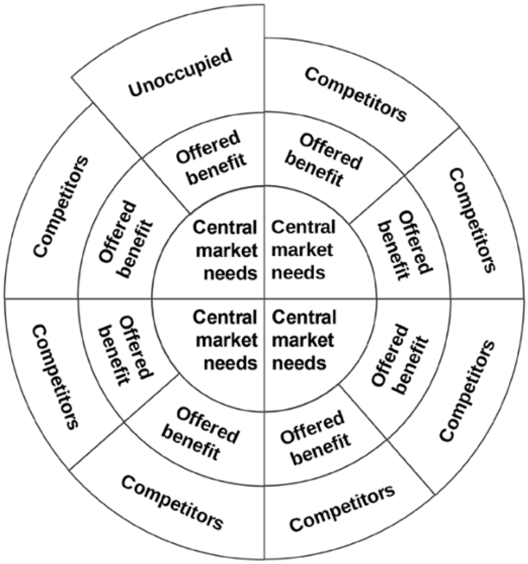


Figure 1.1 Optimal positioning in the sales market[6)]

The results of customer analysis, competitor analysis, analysis of one's individual situation and, finally, positioning in the market influence the preselection of bids. The preparation of an offer involves considerable time and effort. The calculation process requires personal and financial resources. In this way, the company faces order procurement costs:

Order procurement costs = ‰ Costs of volume of supply x hit ratio

Limit: Order procurement costs $\leq$ 2 %

The order procurement costs should not exceed two percent. Two strategies are conceivable (cf Figure 1.2):

1. The company always offers and calculates only superficially. The comparatively low bidding costs therefore result in a poor hit rate: approx. 20 inquiries must be processed in order to receive an order.
2. The company selects the inquiries that best correspond to the chosen enterprise strategy for the range of products and services. The offer is vetted and fundamentally calculated. The higher costs are thereby leveraged by a higher hit ratio (only approx. four cancellations per hit).

6) Cf. Weissmann / Schwarz (1997), p. 110.

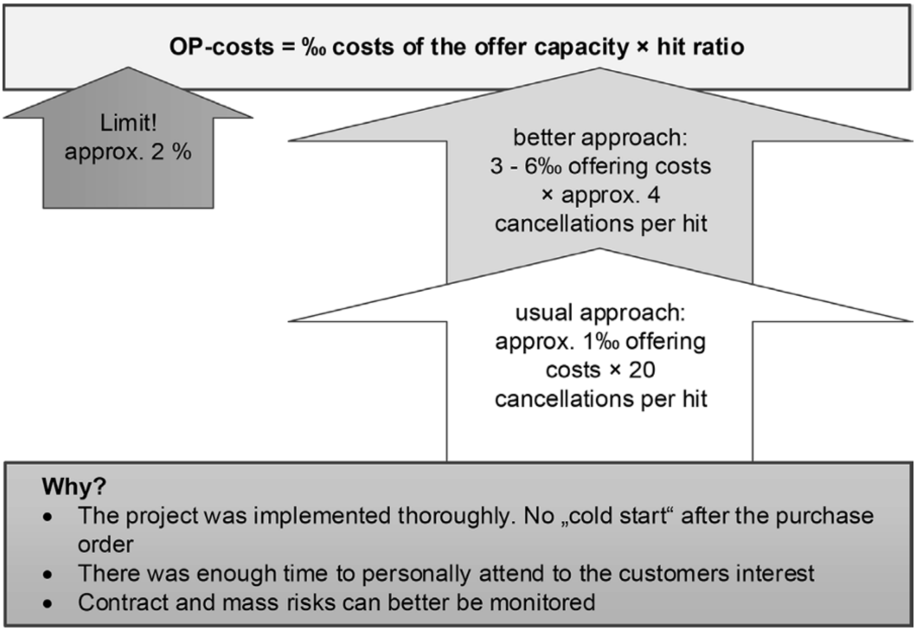


Figure 1.2 Order procurement[7)]

With the second strategy there is no cold start after the placement of the order. Enough time remains to attend to potential customers and learn about subjective aspects. Contract and mass quantity risks are also more under control. This only works when inquiries are selectively processed. Thus the strategic preselection of bids is of utmost importance.

For defining a result-driven strategy for the preselection of bids, customer analysis, competitor analysis, analysis of individual situations, and, finally, positioning in the market are necessary (cf. Figure 1.3). This strategy must be constantly adapted and modified by management to complement the current situation.

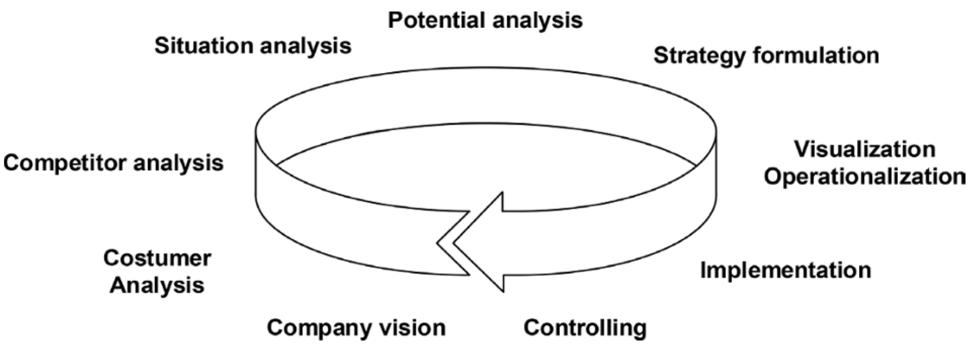


Figure 1.3 Strategy and management

7) Hochtief Software GmbH, Essen.

1.2 Production and procurement strategies[8)]

In the construction contract, the construction company is engaged as the contractor, the construction product suppliers and manufacturers as subcontractors. For the completion of a structure, please see the indicated academic literature on construction business management.[9)]

Procurement strategies

Together with the procurement of construction materials, equipment and subcontractor services, it is possible to distinguish a strategy among the dimensions of high-need fluctuations, purchasing market complexity, and importance of the procurement procedure for the company[10)]. With individual production, it is possible for individual procurable product needs to arise from high need fluctuations; accordingly, the procurement portfolio is developed from the dimensions of high need fluctuations, purchasing market complexity, and importance of the procurement procedure for the company. To investigate the importance of the procurement process, the ABC-Analysis can be applied. Using this method, the goods to be procured can be classified as follows:

- *A-Goods* cover a very high percentage of value consumption every year
- *B-Goods* approach a mid-ranged percentage of value consumption every year
- *C-Goods* are characterized by a low percentage of value consumption every year

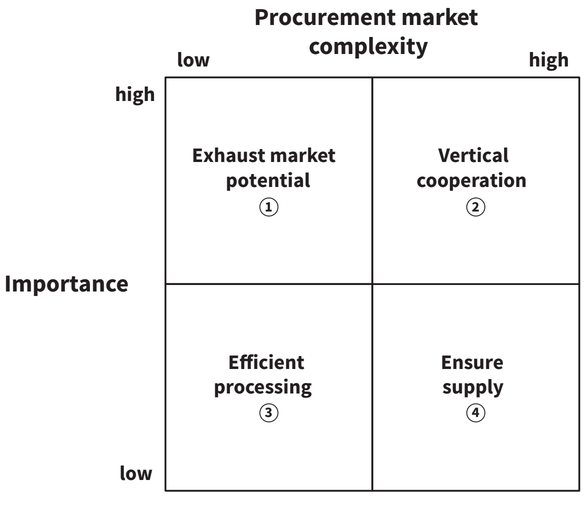


Figure 1.4 Procurement strategies

8) Weissmann / Schwarz (1997), p. 123.

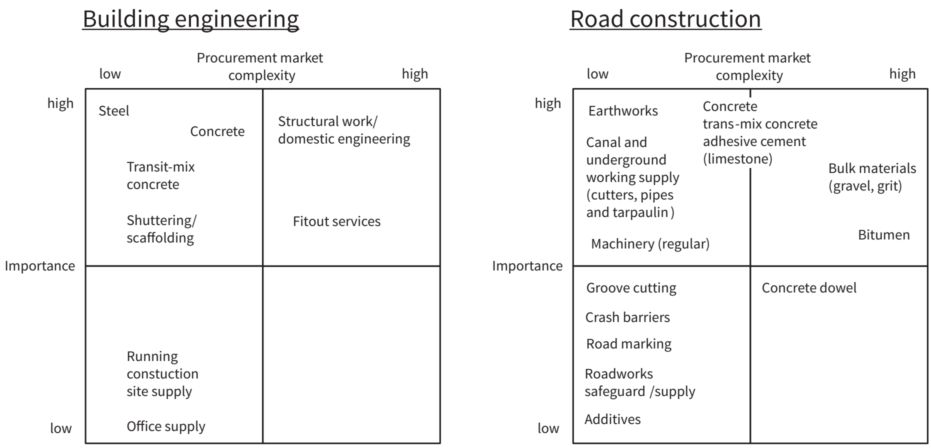
9) Cf. See also e. g. Berner / Kochendörfer / Schach (2013) and Berner / Kochendörfer / Schach (2015).

10) Cf. Hamm (1997). Especially for purchasing subcontractor services, Jacob / Leinz (2005), pp. 5–7.

The individual fields of the procurement portfolio can be arranged in the following strategic options:[11)]

– With low procurement market complexity, a market-oriented approach is used (market-oriented procurement process type), i. e. the market potential is exhausted, as the provider with the lowest price is chosen (Field 1 in Figure 1.4).
– If the procurement market complexity is high, a careful approach in the form of vertical cooperation is advantageous (risk-induced procurement process type (Field 2 in Figure 1.4).
– With low procurement market complexity and low procurement importance of goods, a strategy of efficient management and/or the minimization of transaction costs come into play (Field 3 in Figure 1.4).
– For goods whose procurement market complexity is high, but which are of lesser importance to the company, the supply should be strategically provided for (Field 4 in Figure 1.4). This can be achieved, for example, by backing up the supply with not only one, but two suppliers or by increasing the quantity stored.

Appropriation to the sectors of the construction industry
The individual fields of the procurement portfolio can be arranged by their compatibility with other purchased goods in their sector. In Figure 1.5, there are outstanding examples of companies and their corresponding sectors, namely building construction, road construction, specialist foundation engineering, and steel construction. Thus, not only the purchasing volume but also the critical path of a construction site define the meaning of a procurement system.



11) Cf. see also Jacob (1998), pp. 40–45 and Leinz (2001), pp. 10–12.

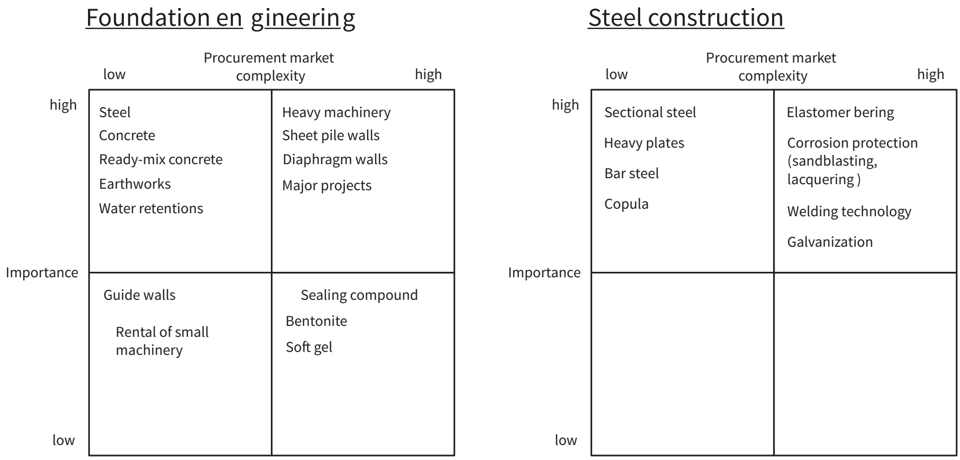


Figure 1.5 Procurement portfolio dependent on the sector

For instance, the procurement strategies must be supplemented in the building construction sector:

- The *exploit market potential* strategy is especially suitable for construction materials such as steel or cement. Moreover, low complexity on the procurement side also includes the required support supplies, such as construction devices and machines, as well as formwork and scaffolding in building construction in general. Diverse contractors, who all offer comparable qualities, exist in the market. The importance of the procurement categories is, therefore, particularly high for the company because of the quantities to be built and the required time.
- A *vertical collaboration* is recommended for subcontractor assignments such as construction excavation and structural work, for home utilities and for general finishing work. If one pursues the development of the classic company to become a full-service provider, the increasing importance of the subcontractor assignments becomes apparent. The subcontractor portion for mid-sized companies can also amount up to and even surpass 50 % of the entire purchasing volume.
- The *efficient settlement* strategy is of importance for the so-called C-Goods and everything that falls under the category of overhead. Examples of C-Goods include objects for the continuous construction site supply; overhead products refer to procurement supplies of general business activities such as office supplies. These are less important for the purchasing volume of the company.[12)]

Price escalation clause
A price escalation clause is an agreement between producer and customer which makes the sales price dependent on the development of a command variable between a basic and a revised amount (i. e. price index, market price, procurement costs of the production factors). Full and partial clauses differentiate from one another. In the case

12) Concerning the optimal purchase strategy of C-goods and overhead products cf. Hamm (1997), p. 139 ff.

of a partial clause, only a part of the sales price changes with the command variable. An exact definition of the basic and revised amounts is essential in this context.

With the completion of long-term contracts, as construction contracts are represented, the customer should be aware of price risk on account of the contractor (risk of retroactive price adjustments for input factors) due to the agreement of price escalation clauses. The establishment of the price thus depends on the development of specific cost indicators. To this end, a price escalation clause is made, which establishes the included cost factors and their appropriate quantity.

In the German construction industry, material price escalation clauses are used for steel[13)] and for public construction contracts in road and bridge construction[14)]. In this way, the additional or lesser expenditures for every material listed in a catalog will be recalculated using the difference in price on the day of construction. Another possibility is to use the market prices previously given by the contractor and their associated catalog date (generally the time of shipment of quotation documents at net price). With this agreement, financial problems still arise. The price that a construction company actually has to pay for construction material is determined at the time of purchase and not at the time of use. Because the market price can nevertheless have changed again between the time of purchase and use, a disadvantage or advantage on behalf of the contractor is not to be dismissed. For this reason, it would be financially justified to have a price escalation clause to compare the price of construction materials at the time of purchase with the price upon the completion of the contract.

1.3 Financing strategies

Securing liquidity is of very high, frequent, and vital importance. In the construction process, very highly advanced services are rendered that can only partially be covered by advance payments. Construction equipment, wages, construction materials, scaffolding, framework, pit lining supplies, external services and so forth are to be paid for (cf. Figure 1.6). Subsequently received down payments or final payments come at a later time: with respect to down payments, the what is received is based on the percentage of completion, and the final payment is due upon full completion of the project.

13) EFB StGl-319, decree of 04/2008 as well as decree of 23/03/2009 of BMVBS – extension or the federal building construction until December 31, 2010 of the material price escalator clause for steel.

14) HVA B-StB 03/09 - Manual for the award and performance of construction service in the road construction and bridge construction, hardback March 2009.

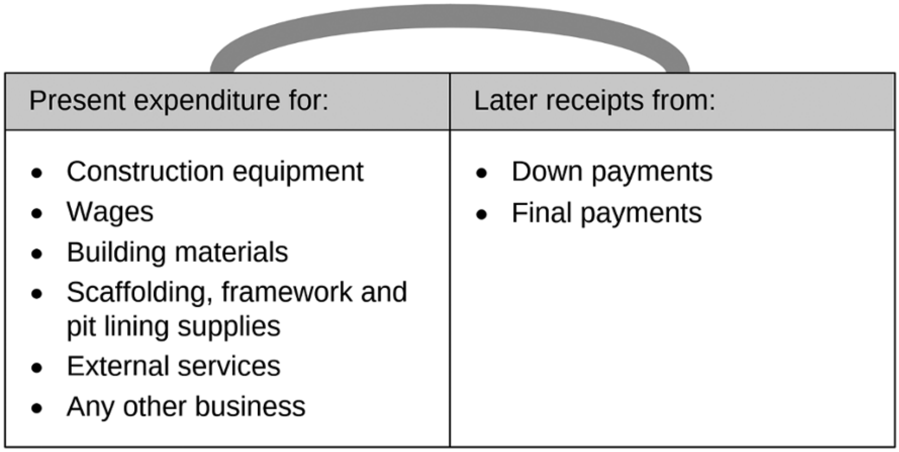


Figure 1.6 Liquidity risks of construction companies[15)]

The typical seasonal development of receipts and expenditures for building construction and road construction companies are displayed in Figure 1.7. In spring, when the weather allows construction activity to start up again, expenditures grow rapidly as well because construction companies must begin advanced services of their pending projects. Receipt of payments lag behind, so strains of liquidity often occur through the fall months. Therefore, appropriate liquidity planning is necessary, as is presented in Chapter 2.1.7. In the last quarter of the year and the first quarter of the new year, received payments generally exceed expenditures. This is partially due to the fact that many construction projects are settled at the end of the year. This context, as well as a schematic representation of a model company's liquidity in a single year, are illustrated in Figure 1.7 and Figure 1.8. Naturally, this business model can vary in individual cases, for example, in specialist foundation engineering or finishing trades.

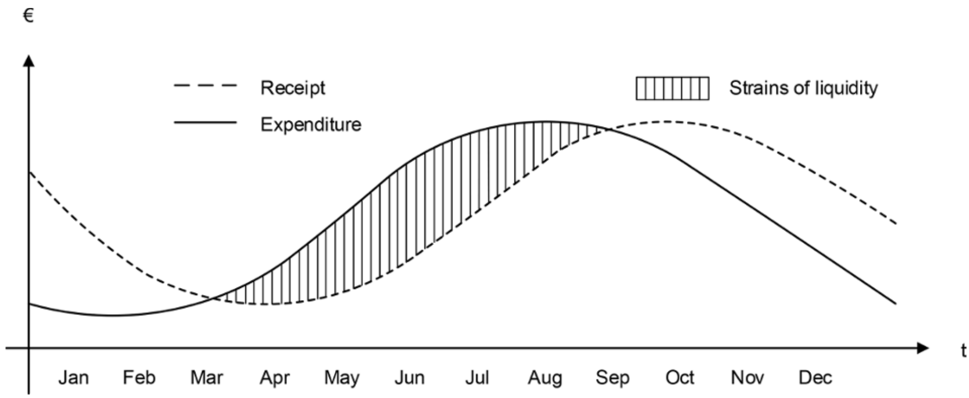


Figure 1.7 Typical seasonal flow of receipts and expenditures

15) Jacob (2000 a), p. 53.

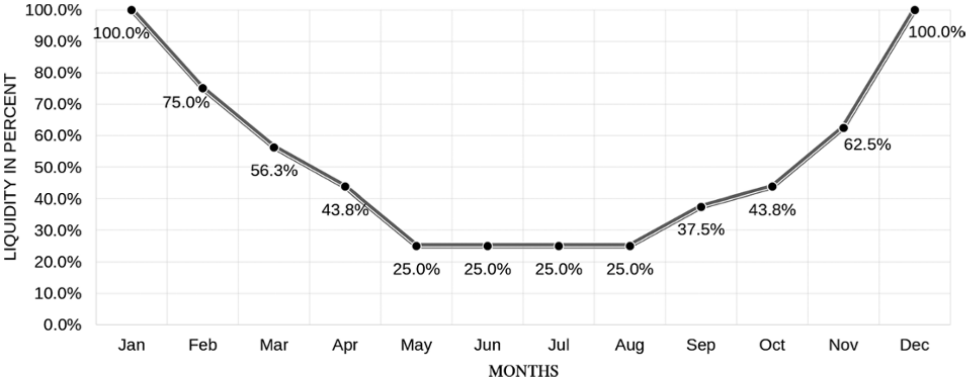


Figure 1.8 Schematic liquidity of a model construction company

In respect to the financing strategy, the bonds are of great importance. Here, the contract performance bond and warranty bond are worth mentioning. These can constitute an even greater volume than the total assets of a construction company. Therefore, bank bonds should be counted among the loans according to the German Credit Services Act. For this reason, and due to the equity regulations for banks according to Basel II and III, construction companies primarily acquire surety bonds.

2 Estimating costs in heavy construction

2.1 Foundations of construction business management

2.1.1 Estimating goals

The cost estimate is structured according to Figure 2.1:

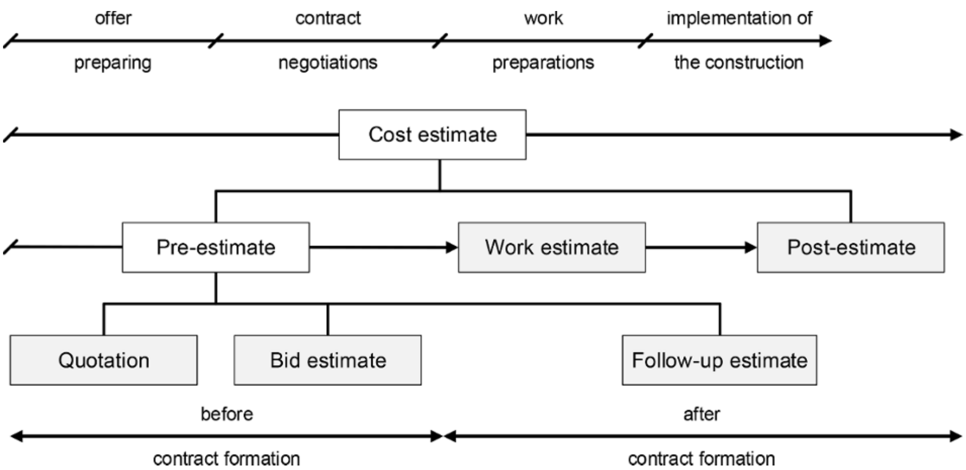


Figure 2.1 Cost estimate structure before and after order placement[1)]

The goal of forecasting is to determine the production cost basis of a construction project with respect to the processing costs, including all capital costs.[2)] This is used as the baseline for negotiating prices with the potential customer.

In our financial system the price is determined by the market and therefore is not directly related to the production cost basis for a product. Management thus requires further accounting information for the negotiation of prices, for instance the lowest price limit or liquidity costs. In addition, due to “target costing”, this preliminary, projected calculation adds to the importance of the retrograde calculation.

When planning target costs, one starts with the market price and subtracts what individual project components may cost according to the predominant market price.

Time-variable costs also remain important. The time-dependent costs are decisive and result from the construction plan, which takes the form of a time-performance diagram.

A further goal of forecasting could be to obtain information about the prospective liquidity development of a project before signing the contract. This may be done in order to recognize the need for liquidity - or excess liquidity - and to determine financing costs.

1) In accordance with Drees / Paul (2015), p. 20.

2) Cf. Hauptverband der Deutschen Bauindustrie e. V. / Zentralverband des Deutschen Baugewerbes e. V. (Ed.) (2001), p. 30.

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2.1.2 Key financial cost terminology

2.1.2.1 Delimitation of costs and expenses

It is necessary for the terms “total expenses of the financial accounting” and “total costs of the management accounting” to be clearly separated (cf. Figure 2.2).[3)]

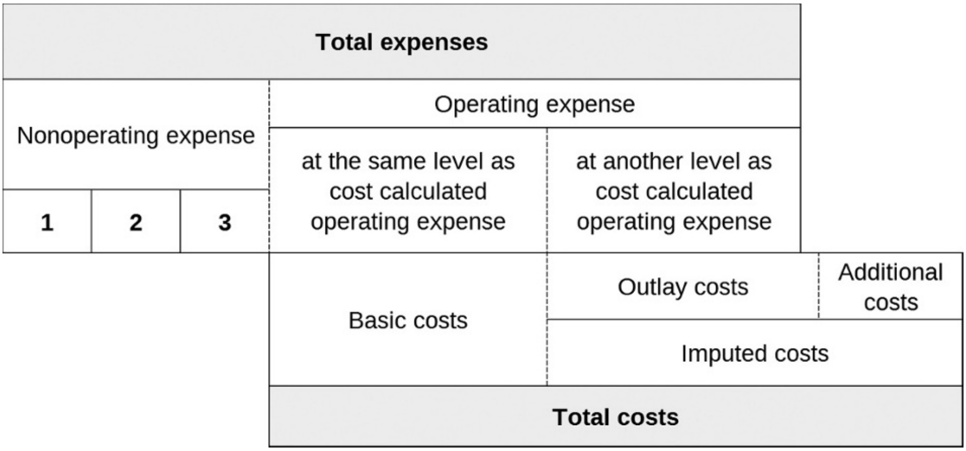

Figure 2.2 Demarcation of the terms expenses and costs[4)]

The total expenses consist of non-operating expenses and operating expenses. The non-operating expenses relate to (1) other periods (2) external expenses or (3) extraordinary expenses. The expenses relating to other periods correspond to the expense of previous business years, for example, additional tax payments. External expenses arise through the pursuit of non-operational goals (e. g. charity). Expenses that are usually not expected in the context of ordinary operational procedures (e. g. fire damage) belong to extraordinary expenses.

The part of the operating expense that is calculated as being equal to the costs represents the basic costs in the management accounting. Examples of this include, but are not limited to, the consumption of construction materials, wages, salaries, or subcontractor expenses.

The part of the operating expense that is calculated as being different to the costs constitutes the outlay costs (i. e. imputed instead of balance sheet depreciation) in internal accounting. The costs not faced with coinciding expenses are referred to as additional costs (i. e. imputed management wages, interest payments on equity, etc.). Outlay and additional costs constitute the imputed costs. Together with the basic costs, these constitute the total costs.

3) The following parts are excerpts from Jacob / Winter / Stuhr (2008), p. 1112.

4) In accordance with Eisele (2011).

Finally, the operating expense and the running costs only differ with regard to outlay and additional costs. This is very important for management, because the period costs used by management must be, to the greatest possible extent, equal the operating expense of the financial accounting (cross-check by offsetting and reconciliation).

2.1.2.2 Direct costs and indirect costs

In the estimating process it is exceptionally important to differentiate costs according to their imputability.[5] Therefore, direct costs and indirect costs can be differentiated. All costs that can be directly attributed to specific cost units (e.g. building part), belong to the direct costs. Direct costs are used in cost type accounting and are assigned to a cost object. A cost allocation across multiple cost objects cannot occur. The types of costs that can only indirectly be attributed to a cost object by way of redistribution or remuneration are considered non-costs. The artificial indirect costs constitute a unique situation. These can theoretically be directly accounted to a cost object, but are nevertheless treated as indirect costs for financial reasons.[6] Examples could be additional materials or certain small materials (i.e. screws).

2.1.2.3 Time variable –time fixed costs

Proper costing of a planned construction project necessitates the differentiation of the prospective costs according to their chronological order.[7] While some types of costs change according to the duration of the construction project, others are set only once and are hence independent of the construction time. Thus, classifications of both time-variable and time-fixed costs can be made.

Time-variable costs of a construction site include:[8]

- Contingency costs[9] (equipment, special plants and machines, accommodation, trailer, contractor’s shed, vehicles, fixtures, office equipment, scaffolding, framework and pit lining supplies, external and safety scaffolding, security facilities, and traffic control installations)
- Operational expenses (equipment, special plants and machines, accommodation, trailer, vehicles)
- The expense of the site management (supervision and coordination)[10] (salaries, telephone, postage, office supplies, automobile and travel costs, hospitality and advertisements)
- The general construction costs (auxiliary e.g. for security staff, surveying assistants, supply costs for the construction site, maintenance costs of paths, squares, roads and

5) The following remarks are extracted from Jacob/Winter/Stuhr (2008), p. 1102 f.

6) Cf. Götze (2010), p. 20.

7) The following remarks are extracted from Jacob/Winter/Stuhr (2008), p. 1103 f.

8) In accordance with Drees/Paul (2015), p. 90.

9) In the case of a longer construction time the construction project has to be charged with a higher proportion of contingency costs for the operating supplies used.

10) In the event of an extension of the construction time, the construction project will be burdened with a higher proportion of labor costs.

fences, lease and rent e.g. for accommodations, offices, construction site facility locations, time variable costs)

Time-fixed costs of a construction site include:[11)]

- Time-fixed costs of the construction site facilities (loading costs, freight costs, assembly and disassembly cost for equipment, accommodation, site trailers, trailers, telecommunications, water supply/sewage disposal, access, paths, fences, work bays and storage place, all kinds of scaffolding, security facilities and traffic control installations)
- Costs of the construction site equipment (auxiliary material; small agricultural equipment and tools, office equipment, accommodation, sanitation facilities, so far as they are not already included under contingency costs)
- Engineering processing and technical control (structural editing, work preparation, construction material tests, soil analysis)
- Construction risks (unique risks arising from the construction process which are confined to the construction project, e.g. adverse weather, high and low water, limited construction times leading to time limit violations and subsequent contractual penalties, the implementation of new construction methods; insurance covering all unique risks arising from the construction process throughout the project's operations)
- Additional charges (abnormal construction interest; license fees, working group costs for both technical and business management, additional provisions for winter construction, and other individual costs)
- Disposal of construction waste and/or construction material (excavated earth, construction rubble, construction debris, road surface material, special waste e.g. colorants and packages of paints, mineral oil etc.)

A differentiation of the costs according to their chronological behavior is also necessary when estimating special cases, namely cases regarding changes in the cost range after the contract terminates and disruptions of the construction schedule (cf. section 3.1). In conjunction with estimating special cases, which may cause a reduction in the contractually established scope of performance, the extent to which costs are remanant should also be examined. Cost remanence indicates that the costs decrease more slowly as a result of a decrease in activity than they rise as a result of an increase in activity. It follows that there are certain costs that are not extractable in the short-term. An example of this is the use of special construction materials that the contractor has already purchased, which, as a result of the reduction in the scope of performance, are no longer needed to their full extent and are also unlikely to be utilized by construction projects in the foreseeable future.

2.1.2.4 Company related – project related costs

Company related costs, i.e. those costs that originate from all operations of the company, which are attributed to the establishment's location and the central headquarters include:[12)]

11) In accordance with Drees/Paul (2015), p. 90.

12) Jacob/Winter/Stuhr (2008), p. 1104.

- Short-term non-degradable costs that guarantee the readiness of production, e. g. wages and salaries of the senior staff (including legislation and agreed social costs), rental costs, depreciation and interest costs of constructions and equipment
- Cost of lighting, heating, cleaning, office equipment, phone, marketing, legal expenses, and consulting fees etc.
- Cost of the construction yard, repair workshop, vehicle fleet
- Taxation or public charges
- Contributions to organisations
- Insurance, as far as it does not concern individual construction projects,
- Transaction costs (costs of initiation, agreement, settlement, alignment, and auditing of contractual relations), including the costs of unsuccessful acquisition attempts
- Cost of enterprise-related risk
- Costs of warranties and sureties (basic fee)
- Imputed entrepreneurs' salary

Project-related costs are especially contributed to:[13)]

- Cost of construction materials, auxiliary construction materials, and operating supplies
- Cost of third-party work and subcontractors
- Costs of loading, freight, assembly, modification, and dismantling of the company equipment
- Transportation costs of construction site supplies
- Cost of energy, water, waste water, and telecommunications
- Costs of the construction, maintenance and repair of entry-ways, paths, barricades (e. g. fences), storage facilities, cost of traffic security
- Miscellaneous costs from leasing and renting
- Cost of construction waste and / or construction material disposal
- Costs arising from project-specific risks
- Cost of project-specific insurance
- Cost of guarantees and sureties, in so far as they are performance dependent,
- Cost of weather-related compensation
- Cost of legal project auditing
- Cost of interim financing for the construction project related loan costs,
- Other costs (e. g. local advertising costs, travel costs, special joint venture costs)

Project-related overhead costs, which can only partially be imputed to the project, include imputable time-dependent depreciation for the operating supplies and the costs of preventive maintenance.

2.1.2.5 Liquidity-related and non-liquidity-related costs

The differentiation between liquidity-related and non-liquidity-related costs plays a very important role in price policy considerations.[14)] Essentially, the offer price should cover the liquidity-related costs. When computing the lowest price limit for maintaining liquid-

13) Jacob / Winter / Stuhr (2008), p. 1104.

14) The following remarks are extracted from Jacob / Winter / Stuhr (2008), p. 1105 ff.

ity, costs that become cash-effective only in the long-term are not covered in the computation.[15] This includes interest on equity and the depreciation of equipment, machines and property. For the calculation, other essential purchases must also be considered. The lowest price limit for liquidity maintenance, therefore, is determined as follows:

	Net offer sum
–	Risk and profit
–	Interest on the equity capital
–	Depreciation of constructions, equipment, and equipment
=	Lowest price limit
+	Essential purchases
=	Lowest price limit for liquidity maintenance

2.1.2.6 Capital cost

The concept of capital cost stands in the context of the requirement of return on investment (RoI).[16] For the use of dept capital, a requirement for a minimum return on investment is defined according to the rights and duties of the related financing and by the risks of investment. The cost of capital includes the borrowing cost of capital, equity financing cost, and the transaction costs associated with the purchase, management, and repayment of the capital.

The borrowing cost of debt financing are costs that result directly from the borrower's credit relationship, including the acquisition fee and disagio, and possibly a risk premium (credit spread).[17] Equity financing costs differ by business entity type, which range from individually owned companies, such as sole proprietorships or business partnerships, and corporation-based companies, such as limited partnerships or corporations. In the former case, the costs are defined according to the investment alternatives of the shareholders, because they expect a rate of return on their capital investments that is at least as high as the most favorable omitted alternative.[18] Should the individual investment alternatives have different levels of risk, a risk premium should be calculated. For corporation-based companies, the equity costs are derived from the sum of shareholder claims with respect to dividends and the value appreciation of shares. Here, alternative investment forms also play a role. The (total) capital costs are determined by the sum of the weighed costs of debt and equity financing.

The weighted average cost of capital with respect to the capital market is usually determined using the capital asset pricing model (CAPM).[19] Because a large number of construction companies are unlisted, the necessary beta factor for the cost-of-equity

15) Cf. a construction related depiction: Speer (1997), p. 157.

16) Cf. the comments below on Drukarczyk (1998), pp. 404–407 and Süchting (1998), p. 745.

17) Cf. the comments below on Perridon/Steiner/Rathgeber (2009), p. 495.

18) Ibidem, p. 495.

19) Cf. for instance, Gladen (2014), pp. 119–126.

rate cannot be determined. The determination of capital costs in the construction industry can be illustrated as is presented in section 2.1.7.3.

2.1.3 Types of construction contracts

In practice there are a number of different types of contract. The most commonly used construction contracts are:

- Unit-price contracts
- Lump-sum contracts (global and detailed lump-sum contracts)
- General contractor contracts
- Output-oriented construction contracts (also referred to as Funktionsbauvertrag)
- Turnkey construction contracts
- Guaranteed maximum price (GMP)
- Operator contracts
- Renovation contracts
- Contracts for the entire life cycle of a construction project, such as build, operate, transfer (BOT) contracts and public private partnership (PPP) contracts

The technical specifications of a construction contract may be input or output oriented. The unit-price contract is typically input oriented, whereas the functional construction contract is typically output oriented.

All types of contracts can either cover the entire life cycle or phases thereof, meaning the planning, construction, and/or operation phases. In each individual phase there may be subsections, such as planning permission or construction services planning, or a planning of the entire phase, as is in the example here of general planning. The same applies to the construction phase. This may also be applicable for a single project subsection or for an entire construction project, in which case a general contractor contract would be used. The interfaces within a life cycle phase or between life cycle phases have to be covered by additional specialists, such as project managers.

Among the different types of construction contracts, there are varying distributions of risk between client and contractor. In particular, with output based specifications, it is also possible for a contractor to introduce certain innovations in several ways.

Due to the importance of both unit-price and lump-sum contracts in practice, these two types of contracts are now explained in more detail.

The *unit-price contract* includes a bill of quantities and a description of the partial services or items to be executed, which is part of the contract's underlying specifications. The bill of quantity contains the expected quantity, the unit price determined by the contractor and the total price (derived by multiplying the quantity by the unit price). Individual items can be listed as flat rate and compensated accordingly (e.g. construction site facilities). In the unit price contract, the total compensation is determined only after the completion of the work. This is because specified antecedents in the specification are variable and can serve only as guidelines. The billing of the services rendered is measured according to the actual quantity. If the parties agree that special regulations are to be applied that regulate additional or reduced mass units, the unit price can be adjusted (Cf. section 3.1).[20]

In *lump-sum contracts,* the technical performance specifications are consolidated and compensated as a work package. In the literature, there is a subdivision of the lump-sum contract into a detailed lump-sum contract and a global lump-sum contract. A feature of the detailed lump-sum contract is that the type and extent of output demanded is determined by detailed specifications provided by the client or mandated by the client's respective documentation, for instance, via construction plans.

In global lump-sum contracts, the performance specifications are generalized and output-oriented. The work preparation, therefore, focuses on the realization of the construction specifications rather the resources or partial activities used to create the contractual agreed service. In the global lump sum contracts, both the compensation side and the performance side are subject to a lump sum. An important feature of this type of contract is the shift of design functions to the contractor.

This generalization on the performance side can take place through a series of steps; the transitions between the two types are often blurred. There are many similarities between detailed lump-sum contracts and unit-price contracts. For example, if the monthly measurement is omitted in the unit-price contract, it automatically turns into a detailed lump-sum contract. Lump sum consolidation merely covers the compensation or earnings side of the contract.

There is a worldwide trend for clients to award design and construction services as a bundled package to use synergies, to exhaust as few of one's own resources as possible, and to save both time and money.[21] The responsibility of a single contractor for the design, planning and execution of a construction project permits an efficient design and construction process. Thus, the quality of design plays an important role in achieving a successful result. This depends largely on how well the construction company manages to integrate design, planning, and construction into a suitable organizational form.

The individual steps in the development of design and bid preparation are basically identical to those of a traditional award of contract. However, there do exist contractual and organizational differences that can lead to a differing approach.

In Germany, the functional construction contract (Funktionsbauvertrag) is widely used in public road construction. It includes additional technical contract specifications[22] that regulate the functional requirements of the road surface in terms of condition and damage characteristics at the inception, over the lifecycle of the road. It also includes ways of monitoring first the functional requirements; second the measures of not fulfilling the requirements in form of a penalty system; and third the downtime costs due to traffic delays caused by road works.

20) If the regulations of the German VOB part B are applied, the unit price becomes fixed to an issued fluctuation range of 90 % to 110 %. Outside this range, the unit price can be adjusted.

21) Cf. also the comments The American Institute of Architects (2003).

22) In Germany, these regulations are called „Zusätzliche Technische Vertragsbedingungen und Richtlinien für Funktionsbauverträge im Straßenbau (ZTV-Funktion StB)“.

The *functional construction contract* is divided into the following three parts:

- Part A (conventional): includes all the construction services that are not dedicated to the bound superstructure. It includes earthworks, drainage, construction, equipment, and traffic safety. This part is designed as a unit-price contract.
- Part B (functional): includes the construction of the superstructure, namely the frost and base layers, the binder layer for asphalt with higher load capacity, and the surface layer. The superstructure will be awarded based on a description of services and a performance program. The compensation is lump sum based.
- Part C (maintenance): includes the structural maintenance of the components, which were created in Part B. This includes maintenance, repair, and renovation (without measures of operational maintenance). These services are made functional upon a description of services and a performance program.

The use of the functional construction contracts results in a partial shift of risk to the contractor. It also offers the opportunity to adjust the structural design to ensure a cost-effective maintenance. However, sticking to the conventional allocation methods for earthwork projects and always maintaining close alignment to standardized road superstructures[23)] can restrict innovation and the potential for optimization.

The *GMP contract* is a contract model that is intended to building a partnership between client and contractor, but is not explicitly regulated by law. This model includes elements of a lump-sum contract and a cost-reimbursement contract. The contractor guarantees the customer a maximum or cap price. The settlement of accounts occurs upon completion of the work and is carried out according to the "open books" principle, meaning that the contractor must disclose its production costs to the client. Cost savings and price shortfalls are therefore divided according to a contractually agreed formula between the two parties. The contractor must usually bear the cost of anything exceeding the maximum guaranteed price alone. In order to ensure that the contractor or general contractor can submit a price guarantee, the contractor should ideally be involved in the design and development phase of the construction. Another feature is the jointly conducted selection and appointment of subcontractors by both client and contractor. GMP contracts can also help to obtain the financial close and to integrate all project participants into a successful work group. In practice, the effects of the incentive measures on the financial outcome of GMP contracts are contentious, as recent studies have shown[24)]. However, there exist a number of discrepancies with the ideal standard contract.[25)]

23) In Germany, the composition of the road types is regulated by the Guidelines for the standardized superstructure (Richtlinien für den standartisierten Oberbau [RStO]).

24) Anvuur/Kumaraswamy (2012).

25) Cf. for GMP-contracts: Fink/Klein (2008), p. 78 ff.

2.1.4 Estimating methods

2.1.4.1 Cost-plus pricing

Cost-plus pricing is commonly employed by multi-product companies in the stationery industry where significant differences in the cost structure occur. Therefore, this method finds application in steel construction, in precast plants or in industrial crafting (such as carpentry, metalworking, heating, ventilation, and plumbing). When employing the method, single supplement costs are allocated directly to cost objects. Overheads are allocated to cost objects with the help of percentage surcharges. Of the many different variants of cost-plus pricing, full cost-plus pricing and differential cost-plus pricing will be briefly touched upon in following paragraphs.

Under full cost-plus pricing, overhead costs are allocated in their entirety as a (cumulative) surcharge to cost objects. Here, the surcharge rate is the ratio of the total overhead and the surcharge basis (e. g. total direct costs). In the case of differential pricing supplements, the allocation of overhead costs is differentiated by cost centers.[26)]

The *estimation of the bid amount*, as a classic method of calculation, is employed in the construction industry – particularly, in cases where blue-collar workers conduct labor-intensive work. [27)] The procedure calculates for each object individually:

– The direct costs (e. g. wages, equipment, construction materials, external services) and
– The costs of the construction site.

Then, overall business costs, risk, and profit are added.

Therefore, this calculation method is a type of cost-plus pricing.

In order to arrive at unit prices for the completion of scheduled services, the sum of construction site costs, overall business costs, risk, and profit are apportioned to individual costs of the partial activities in accordance to a particular key.

Due to the addition of risk and profit, this form of calculation assumes:

– A specific recurring payment behavior of the customer and thus a constant percentage of capital requirement for all construction projects
– A constant risk ratio for all construction projects so that, in theory, all risk factors listed in section 3.3 are transformed into a constant risk premium.

Machine-hour estimation is used for machine-intensive and device-intensive work performed by fixed-station operators. This method is commonly employed in specialized civil engineering projects, tunnel construction, and in automated prefabrication factories. For example, in specialized civil engineering projects, the costs of a "functional unit", consisting of the equipment required and associated employees, is determined based on a single working day. To that extent, this calculation method is a deviation from the pure machine-hour estimation process, in which the machine-dependent overhead costs (e. g. depreciation, fuel costs, maintenance, and repair costs) are broken down with the help of

26) For these particular remarks, cf. e. g. Götze (2010), pp. 112–119.

27) The following comments are excerpts from Jacob / Winter / Stuhr (2008), p. 1113.

the equipment reference period. Here, the machine-hour rate is calculated as the quotient of the sum of the usage of each machine's associated overhead costs and the (target) machine running time. The overhead costs of the cost objects are the result of a multiplication of machine-hour rate and claimed machine run time. Clearing overhead costs independent of machines (residual overhead costs) is done either as a surcharge to the direct costs or other references. The application of machine-hour estimation is generally restricted to the distribution of manufacturing overheads.[28]

The *merchandise trading calculation* is applied in projects concerned with large numbers of subcontractors and material-intensive projects.[29] Increasingly, general contractors appear only as coordinators of construction projects and award these, as well as related processes, to subcontractors. The actual physical work is mostly performed by subcontractors. Construction sites are thusly subcontracted down to the second and third levels, respectively. This occurs not only with turnkey constructions most affected by numerous subcontractor trades. Recently, it is also happening in road construction, civil and structural steel projects.

Interestingly, scientific discourse with respect to marketing or commercial trading has virtually ceased dealing with questions of estimation processes and calculation methods. Nevertheless, a good overview is provided by a classic example of calculations for commodity trading businesses introduced in commercial colleges.[30] In commodity trade, it is important at what cost prices (reference price) products can be bought as well as at what selling price they can be sold. The business cycle of the commercial trading firm shows that the estimation begins at the purchase invoice and leads to the bill of sale (see Figure 2.3).

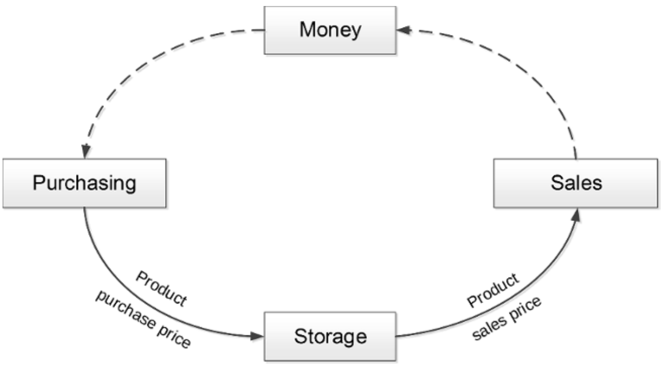

Figure 2.3 Business cycle[31]

The following table shows the scheme of an estimation of commodity trading firms as used in the construction industry (see Figure 2.4). In particular, general expenses that are concerned with construction are comprised of the costs of supervision and coordination of the various subcontractors (general contractor surcharge). For this purpose,

28) Cf. machine-hour estimating in general. e. g. Götze (2010), pp. 119–124.

29) The following comments are found in: Jacob/Winter/Stuhr (2008), pp. 1149–1151.

30) Deuschle/Meffle/Gönner (1993), pp. 157–194. Cf. Bartosch-Schmitz et al. (2005), p. 257 f.

31) Deuschle/Meffle/Gönner (1997), p. 157, cited in: Jacob (1997), p. 507.

highly qualified staff, construction site managers in particular, but also foremen and commercial staff, are required. In addition, the general expenses also include the costs of winning the contract. In case of unsuccessful acquisition efforts, these acquisition costs are charged proportionally to the acquired projects. Furthermore, open items with respect to the risk of warranty, surety fees, credit, quality, and schedule risk of the subcontractors, should not to be neglected.[32)]

	List purchase price (net)	
−	Shipping discount	
=	Target purchase price	
−	Suppliers cashback	
=	Cash purchase price	
+	Purchasing costs	(e.g. Agent's commission, brokerage fees, etc.)
+	Handling costs	(such as freight, cartage, loading, monitoring costs, transport insurance)
=	Delivery price	
+	General expenses	(e.g. staff, rent and occupancy, taxes, mandatory contributions, money circulation)
=	Cost price on purchasing day	
+	Interest surcharge	(for time between purchase and payment of deposit for merchandise sales)
+	Profit surcharge	(entrepreneurial profit and risk premium)
=	Cash sales price	
+	Customer cashback and Agent's commission	
=	Target sales price	
+	Customer discount	
=	**List sales price (net)**	

Figure 2.4 Scheme of a merchandise trading calculation[33)]

2.1.4.2 Capitalized earnings value method

According to the expression "Net annual rent times multiplier minus total costs is greater than or equal to minimum profit", the capitalized earnings value method is used during the estimation process of projects of business developers and in real estate development projects.[34)] The multiplier depends on the prevailing market conditions, which depend, among other things, on the current loan market interest rate and the expected value of the object. A table depicting the project calculation process is shown below (see Figure 2.5).

32) For comments on pricing, cf. Jacob (1997), pp. 505–509.

33) Jacob (1997), p. 507.

34) Most of the following comments are extracted from in Jacob/Winter/Stuhr (2008), p. 1148 f.

Investment costs	**Sale proceeds**	
Property costs	Sale proceeds	= Net annual rent x multiplier
▶ Acquisition costs		
▶ Brokerage commission(s)		
▶ Severance pay and compensations		
▶ Prepariation of property		
Development costs	**Project results (figures)**	
▶ Public development	Gross profit	= Sale proceeds – total costs
▶ Development investment	Return on sales	= Gross Profit/Sale proceeds
▶ Development fees	Gross margin	= net annual rent/total cost
▶ Parking spaces repayments		
Construction costs		
▶ Above ground area (gross)		
▶ Underground area (gross)		
▶ Outside spaces		
▶ Non-public development		
▶ Parking spaces		
Additional costs of construction		
Leasing and marketing		
▶ Commissions		
▶ Advertising costs		
Financing costs		
= Investment costs		
+ Business expenses		
= Total costs		

Figure 2.5 Capitalized earnings value method

For valuation reports for developed or undeveloped property, the capitalized earnings value method is used as an expression of the variant: "Expected future net annual rent times multiplier less rehabilitation costs match present value of developed or undeveloped property". The approach also offers a series of applications in tax law, in business valuation or in infrastructure development projects. Other dynamic methods of investment and financial calculations are used for more complex developments of the cash flows. In particular, this includes the present value method and more sophisticated variants, such as the multiple investment sinking fund method.

2.1.5 Further development of the pre-estimate[35)]

2.1.5.1 Increasing accuracy

A pre-estimate is the conventional German estimation method used to assume that prices were roughly appraised with respect to cost and contract estimations. The actual, more refined estimation, including construction schedules, selection of construction methods etc. takes place in the work estimate after contracts are assigned. After the assignment of the contract, it is already too late to efficiently implement these measures because a contractually fixed inaccurate price cannot easily be compensated through "claim management".

Therefore, the refined estimation, which includes construction schedule and selection of construction methods has to start during the phase of bid calculation. For some time, this has been the preferred method in Anglo-Saxon countries. Now, however, it is argued that the previous method was too expensive, and the hit ratio amounts to a mere single contract for every twenty processed offers. The counter-argument says that the pre-selection of the inquiries has to be performed much more precisely. The construction company needs a clear strategy and needs to know its particular strengths and weaknesses - or in other words - has to be aware of its relative competitive edge.[36)]

2.1.5.2 Inclusion of capital cost

In general construction estimating, each building component used to be included in the estimation process for structural engineering projects but, apparently, not the capital costs. This is reminiscent of the old way of thinking: That equity capital is free of cost. Since the advent of the "shareholder value" school of thought, at the very least, it should be clear that the current economic system is characterized by capitalism and economic governance, which is decentralized and money-driven.

The payment schedule of a construction contract has to be adequately considered in the capital costs. In addition to the construction schedule, the preliminary estimation requires a project-specific liquidity plan. The plan should also include cash pay substitutes, such as surety bonds (including warranty bonds). The payment mechanism not only plays a role for capital costs but also for risk distribution. Because the later the payment is received, the higher the risks for the construction company – for example credit risk or the risk of litigation.

Furthermore, the capital costs have to include the "shadow costs". These, for example, are comprised of corporate income tax or the maintenance of legal form, which is required for financial reasons. Particularly in case of bonds, the question should be asked whether the cost of separated equity should be included and to what extent. A bond is no longer granted without a modicum of equity capital or some form of "cash deposit".

Recently, the inclusion of capital costs has been disputed, because competitive costs advantages are lost. In this case, such a contract should be rejected because values

35) The following comments are found in Jacob / Winter / Stuhr (2008), pp. 1169–1171.

36) Cf. e. g. Jacob (2000 a), pp. 52–56.

are eliminated rather than created. The conventional “being in the red” and “being in the black” should be replaced by accurate calculations. Therefore, time-proven trade virtues should be reinstated or enforced by an appropriate monitoring system.[37] A “Nick Leeson” of Baring Bank, after all, might also occur in a construction company. However, management systems should not allow such actions.

2.1.5.3 Evaluation of risks

According to statements by lawyers, even the Federal Court of Justice of Germany now prohibits flat-rate risk premiums of two to five percent. Contract manufacturing and prototyping sectors, such as the construction industry, are prone to take special risks. Certainly, the risks are dependent on the specific construction sector, the extent of the contract, the customer, the type of contract, and the contract content. These are discussed in detail in section 3.3. On the production side, they are comparable to the risks of an automobile company transitioning to a new product type. Accidents and mishaps are thus virtually unavoidable as dictated by the nature of a prototype. The risks need to be determined individually and evaluated according to their probability of occurrence. Also, one may work with best-case, worst-case, and normal-case scenarios and, consequently, demonstrate the range of probability of occurrence. In conjunction with risk management systems, there is certainly room for future research.

2.1.5.4 Consideration of seasonality in construction

In contrast to the stationary industry, the construction industry is highly seasonal dependent[38]. For example, road construction has to be suspended due to the dangers of frost during the winter months. The sharp rises of groundwater levels, which may lead to flooding of the site are particularly feared at excavation sites during winter and spring. Hence, construction in and at excavation sites is more favorable during summer. Conversely, special attention has to be paid to fresh concrete during the summer months as it might burn dry due to solar radiation and could, as a result, not receive optimum hydration and suboptimal solidity. Covering and keeping the concrete surfaces moist is helpful in such cases. These few examples show how seasonally dependent structural engineering is. The season during which a specific project is carried out also plays a decisive role for working hours that are required. In case construction schedules need to be changed e. g. due to delayed construction permits, timetables have to be recalculated from scratch in accordance with the season. Such delays could, at the very least, be approximated via a seasonal factor in pre-estimates.

2.1.5.5 Claim management and anti-claim management

From a contractor’s perspective, the concept of claim management deals with amendments based on changes in the contractually agreed scope of construction projects after contract assignment. This means rescheduling in accordance with any future needs

37) The German “monitoring and transparency for areas of business act” (KonTraG) also requires a risk management system (RMS).

38) Cf. BWI-Bau (2013), p. 86.

of the client or changes resulting from the construction permit or alterations because of changed subsoil conditions. These claims need to be substantially justified. Often, high-priced legal and technical experts are consulted. If the contractor cannot realize these changes with their own workforce, particularly with respect to projects with low own production depth, they are also confronted with the resulting additional demands of the project's subcontractors. To successfully defend itself against such exaggerated claims, the contractor has to establish anti-claim management. Again, this requires a team of cost-intensive legal and technical experts. If the requirements mentioned above are not met, such sites are likely to become "disaster sites" and losses of millions of euros are not uncommon. The projected costs for skilled lawyers, court proceedings, and technical experts must be quantified, especially for projects with little vertical integration. Projected costs for both claim and anti-claim management have to be quoted as special or additional items in the pricing of an offer. An example of the inclusion of costs of claim management and anti-claim management in the estimation process is given section 3.1.

2.1.6 Coexistence of construction schedule, risk management plan and capital commitment plan

Appropriate preliminary calculations should always include a rough construction schedule describing the construction method to be applied. Thus, it is ensured that time-fixed and time-variable costs are clearly separated.

Every engineering construction is characterized by prototype construction exposed to special risks. The main risks need to be disclosed in a separate risk management plan. Then, risks have to be evaluated through cost evaluations. They should be carefully monitored for the entirety of the project.

The following paragraphs list typical risks for the phases of design, construction, and operation.[39)]

Design risks
- Failure of the design concept
- Lack of design quality
- Changes by the client
- Changes by the operator
- Changes that emerge due to external influences (e. g. legislative changes)
- Incorrect implementation of construction specifications
- Insolvency of design offices

Construction and development risks
- Erroneous pricing
- Flawed schedule
- Poor quality of construction services
- Unexpected foundation conditions
- Supplement costs

39) Jacob (2001), p. 11.

– Exceeding the construction time
– Acceleration costs
– Force majeure
– Legislative changes
– Insolvency of contractors

Operating and maintenance risks
– Higher operating costs
– Higher maintenance costs
– Inadequate maintenance
– Availability
– Demand risk
– Technology risk

Specific assessment of the main risks is currently not as widespread as it could potentially be in German speaking countries. In this respect, there is a lot to learn from Anglo-Saxon countries. It seems irrational that only the insured risks in the form of insurance premiums are recognized. The non-insured risks have to be considered in an analogous manner. Here, a knowledge transfer, particularly from the insurance industry to civil and structural engineering industries, is required.

So far, the specific interest costs for the construction period are neglected in Germany. These need to be derived from the project-related capital commitment plan. The bond costs are explicitly derived from a security plan. Furthermore, it is considered that with the payment mechanism, additional risks also can be passed from the customer. This means that there are certain interdependencies between capital commitment plan and risk management plan.

Sections 2.2 to 2.6 mainly deal with the estimation of the individual time-fixed and time-variable costs from the construction schedule. The interest costs and risk costs are still too general. In section 3.3 (Calculation of risks), these aspects are treated more differentially.

Older generations might argue that, recently, no contractor receives acceptance of a bid if both interest and risk costs are included in the estimate. A possible counter-argument might be that more effort should be put into preliminary selection of contracts and organization.

Another objection is that the preliminary estimate is too expensive and time consuming considering the complexity of pre-estimates in conjunction with a construction schedule. In this regard, it is said that it would suffice if such issues were caught up on later in the process after the order has been placed. At that point, however, it is too late; incorrect contracts may have been selected, and losses are inevitable.

For these reasons, the following principles should be pursued: Better strategic pre-selection of offers should be ensured and pre-estimates calculated more accurately. Moreover, appropriate marketing strategies and more sophisticated types of contract should act as buffers against ruinous price competition.

2.1.7 Liquidity planning and capital cost

2.1.7.1 Project-related liquidity planning

The process of liquidity planning is best explained with the help of the example shown in Figure 2.6. The dotted line represents the monthly costs. For the sake of simplicity, costs incurred and date of payment match. In many cases, the differences would be marginal anyway. The thin solid line indicates the regular sales proceeds. As the chart shows, costs arise from day one, whereas the sales proceeds come into view from period nine onwards. In this typical case, the contractor or the developer has to partially pre-finance the projects. The dashed line showing the liquidity level is the result of the cumulative cost-related expenditure and the accrued cumulative liquidity cash receipts. Here, it is shown that the maximum available credit line of EUR 3.8 million is passed at period eight. Therefore, the presented "business plan" is not realizable.

Figure 2.6 Exemplary progression of cash flows[40)]

Hence, the project schedule must not be carried out as initially planned; otherwise, the project would soon become insolvent. In this case, cost curves and sales proceeds, respectively, need to be modified through rescheduling until the credit line is sufficient. Otherwise, the project is not financially realizable. Creation of project-related liquidity plans is actually a rather simple affair, as the example shows, yet this is almost never implemented.

Incidentally, the example shows that approximately EUR 500,000 of capital resources were used in period zero. This amount of equity resources is increased to the amount

40) Jacob (2000b), p. 54.

of EUR 1,000,000 by the 19th period. On a related note, capital profitability may also be determined from the interdependencies shown. The profitability is calculated with the nineteenth root of (1,000/500 = 2) conforming to 3.7 % per period.

A project-related liquidity plan, such as in the example, is not sufficient. Even if the project cash flow for all projects is positive, the contractors may still become insolvent. This is due to the overall costs of operational readiness, e. g. offices have to be financed, costs be paid for unused equipment, and accumulating costs for the head office, auditors, tax consultants, the annual report, and the annual general meeting have to be covered.

2.1.7.2 Company-related liquidity planning

In addition to the project-related liquidity plan, the company-related plan is considered in more detail in the following paragraphs. For business-related financial planning, the one-year financial plan method is important, which is sometimes also called liquidity plan. Due to the duration of each contract, annual balance sheets include concrete planning information for the following year. The financial impact of the existing contracts is known. To achieve the planned production, it is necessary to acquire new contracts, which are to be included estimating the related modalities in terms of time, revenue, costs, and payment terms.

Table 2.1 shows the order intake of a medium-size construction company sorted by contracts. For example, there is a contract sum of EUR 2,274 thousand in the January column, and residual capacities are no longer available. In the February column, contracts worth EUR 6,100 thousand were acquired, but there is still a remaining capacity of EUR 929 thousand there; and, the remaining EUR 800 thousand could be used to employ subcontractors. The sum of the expected order intake, which is highlighted in bold as the last line of the table, is transferred into the planned income statement (see Table 2.1, row 1).

Table 2.1 Expected order intake[41)]

Contract Euro in thousands	**Value**	**Quantity**	**Jan**	**Feb**	**Mar**	**Apr**
Billing plan based on production plan						
BASF	2,600	2,000	600			
Raschig	1,500	1,000		500		
Stadt LW	710			600	110	
GKW Mhm.	25,100	4,530	1,674			
Daimler-Benz, Wörth	7,500	3,330		2,000		
Opel, K'lautern	2,384			1,000		168
Südzucker, Off.stein	8,100	2,000		1,000		
Hoechst, Fm	600					100
Schott, Mainz	500			500		
div.	1,544			500		
Total	50,538	12,860	2,274	6,100	110	268
Residual capacity according to production plan			0	929	1,024	1,030
Subcontractors - planning according to purpose			0	800	0	500
Turnover size – total – Financial Planning			2,274	7,829	1,134	1,798
plus VAT and other earnings			**2,601.50**	**8,934.20**	**1,301.90**	**2,058.80**

With this approach, income statements and cash flow planning are interdependent as far as computation is concerned. Initially, turnover from January to April is incorporated into the planned income statement. On the basis of the planned income statement in the liquidy planning, the payment from the customer is estimated with a certain time lag. This is shown in bold print in line one of Table 2.2. This interdependency between the planned income statement and liquidity planning simplifies meaningful financial and sales monitoring. This form of combined planning is a very interesting approach – especially for specialized production.[42)] The actual contract structure, turnover, and li-

41) Jacob (2000b), p. 54.

42) Cf. in detail Wagner/Klinke (2000), pp. 35–62.

quidity should ideally be discussed at regular management meetings with the executive board (project group sales, production, purchasing, and finance). A quarterly update has proven to be useful from a cost benefit perspective.

Table 2.2 Planned income statement[43)]

Planned income statement Euro in thousands	**Status Jan 1st**	**Jan**	**Feb**	**Mar**	**Apr**
Proceeds					
Plan of proceeds	-9,151.30	2,601.50	8,934.20	1,301.90	2,058.80
Cash / postal cheque	25.00				
Bank deposits	4,698.40				
Capital trend	425.00				
Shareholder loans	51.80				
Total proceeds	-3,951.10	2,601.50	8,934.20	1,301.90	2,058.80
Costs					
Plan of expenditures	3,521.70	1,251.20	1,805.50	959.70	1,146.60
Purchasing plan / credit	5,093.40	1,189.70	3,133.00	2,048.20	2,588.50
Investment plan		0.00	0.00	0.00	0.00
Plan of other expenditures	21.00	17.20	17.20	62.60	17.20
Loan	3,177.20				
Capital	1,083.80				
Total costs	12,897.10	2,458.10	4,955.70	3,070.50	3,752.30
Debit cover	0.00	143.40	3,978.50	0.00	0.00
Deficient cover	-16,848.20	0.00	0.00	-1,768.60	-1,693.50
Cumulative cover development	-16,848.20	-16,704.80	-12,726.30	-14,494.90	-16,188.40

43) Jacob (2000a), p. 56.

Table 2.3 Schedule of liquidity[44)]

Schedule of liquidity Euro in thousands		**Jan**	**Feb**	**Mar**	**Apr**
Proceeds					
Plan of proceeds		4,053.30	4,737.20	4,990.50	3,000.00
Cash/postal cheque					
Bank deposits					
Capital trend					
Shareholder loans					
Total proceeds		4,053.30	4,737.20	4,990.50	3,000.00
Costs					
Plan of expenditures		785.60	1,340.20	664.30	1,277.00
Purchasing plan/credit		2,554.90	3,934.90	3,443.50	2,497.70
Investment plan		0.00	0.00	0.00	0.00
Plan of other expenditures		38.20	17.20	62.60	17.20
Loan		16.50	16.50	18.50	16.50
Capital					
Total costs		3,395.20	5,308.80	4,188.90	3,808.40
Debit cover		658.10	0.00	801.60	0.00
Deficient cover		0.00	-571.60	0.00	-808.40
Cumulative cover development		658.10	86.50	888.10	79.70

2.1.7.3 Determination of capital costs

How a middle-size business may calculate the capital costs is shown by the following German example.[45)] The example is based on an assumed 75 % debt and 25 % equity share. Equity ratios far below this are no longer accepted as being creditworthy by banks. Due to the implicit interest risk, the return on equity capital must be higher than the return on debt capital. The reason is that equity capital is not secured by real property and only bears dividends if income is earned. Furthermore, it should be noted that equity interest earnings are completely subject to the German trade tax. The basis of German trade tax consists of the earnings plus ¼ of the permanent debt interest. The percentage

44) Jacob (2000a).

45) Cf. simplified Perridon/Steiner/Rathgeber (2009), pp. 525–528.

of the German trade tax is calculated with a 3.5 % coefficient of measure multiplied by the individual rate imposed by the municipality (in this example 400 %).

The current German corporation tax rate amounts to 15 % of the earnings.

When distributed, the dividend for the investor is subject to a settlement tax of 25 %. In addition, solidarity surcharge and church tax have to be considered, but are disregarded in this example.

Debt (75 %)

Interest rate: 6 %

14 % (= 400 % x 0.035) German trade tax at 400 % collection rate and 3.5 % coefficient of measure

Inclusion with 25 % (addition of ¼ permanent debt interest)

0.75 x 0.06 x 1 / (1–0.14 x 0.25) = 4.66 % incl. trade tax[46)]

Equity (25 %) – Case accumulation

Interest rate: 8 % (higher than interest rate on debt, because no collateral security possible)

15 % German corporation tax

0.25 x 0.08 x 1 / (1 – 0.14) x 1 / (1 – 0.15) = 2.74 % including German trade and corporation tax[47)]

Cost of capital = 4.66 % + 2.74 % = 7.40 % including company taxes

Equity (25 %) – Case full distribution

Distribution (25 % German flat-rate settlement tax on investors)

0.25 x 0.08 x 1 / (1 – 0.14) x 1 / (1 – 0.15) x 1 / (1 – 0.25) = 3.65 % including business tax and corporation tax[48)]

Cost of capital = 4.66 % + 3.65 % = 8.31 % including company taxes and flat-rate settlement tax on investors

2.2 Estimating of earthworks

2.2.1 Introduction

A number of factors characterize calculation processes involved when pricing earthwork construction projects, which may cover anything from smaller, preliminary earthworks for larger construction projects to earthworks for large-scale projects in the infrastructure construction sector.

46) Corporation tax not included as interest on debt is deductible as business expense; retrograde calculation: 4.66 % – 0.14 x 0.25 x 4.66 % = 4.5 % (= 0.75 x 6 %).

47) Retrograde calculation: 2.74 % - 0.14 x 2.74 % - 2.36 % x 0.15 = 2.0 % (= 0.25 x 8 %).

48) Retrograde calculation: 3.65 % - 0.14 x 3.65 % - 3.14 % x 0.15 – 2.54 % x 0.25 = 2.0 % (= 0.25 x 8 %).

The following section gives insight into how earthwork items are calculated from the perspective of a traffic route engineer and include the main aspects of a large-scale project. Contract documents for large infrastructure projects provide a number of variants to execute earthworks construction. In this context, it is possible to integrate excavation, transport and installation in a single item. The following procedure shows the creation and pricing of an earthworks concept on the basis of the project's specifications and the particular construction schedule provided by the contractor.

Alternatively, the possibility exists to create contracts based on partial activities divided into construction-site excavation and filling areas, quantity division according to a specific timeline, or several other variations within this spectrum.

For integrated earthworks projects, the calculation effort is much higher since the mass distribution plan, together with related transport distances, has to be created by the contractor while bearing in mind both the construction timeline and geological suitability. The advantage of this approach is the possibility of implementing in-house expertise and workflow optimization from a top-down view of the contractor. However, potential for work-flow optimization as well as synergy effects between single items of a detailed contract should not be neglected. An important aspect during the calculation process is the involvement of construction site conditions, but this topic will only be briefly touched upon. The main focus of this section is the handling of calculation procedures.

2.2.2 Construction site conditions

In most cases, subsoil risks are borne by the contractor. Hence, most ensure the inclusion of a subsoil study in the contract. The resulting data has an influence on the calculation process with respect to the qualitative suitability / usability of materials, necessity for additional action, such as soil conditioning or material preparation, and the different performance parameters of excavating and soil-moving equipment depending on the worked material. In particular, the required equipment has a major influence on the calculation process. Short descriptions of subsoil classifications are outlined below. European and German norms provide the basis for differentiation:[49)]

- Soil types according to DIN EN ISO 14688 – 1, (divided into grain sizes, grain shapes, information on dry strength and plasticity)
- Soil classes according to DIN 18196 (soil types classified with respect to construction qualities and divided into main classes and classes with approximately equal substantial structure and material behavior)
- Division into cohesive / non-cohesive attributes, water content
- Geotechnical suitability according to attributes such as compressibility, shear strength, compactibility, permeability, susceptibility to water, erosion and frost
- Classification of rock according to:
  - Model behavior of rock mechanics (e. g. single-body / multibody systems)
  - Specification according to DIN EN ISO 14689-1 (identification and classification of rock)
  - Parting lines and weathering attributes (rock-mechanics properties)

49) Floss (2009), pp. 159–190.

– Resistance and deformation (breaking strength, tensile strength, flexural strength, shear strength, and so on)
– Trapped water in rock formation
– Geotechnical suitability

In German contracts, subsoil is usually classified using the classification method for soil and rock according to VOB / C, DIN 18300. This division is based on the workability of soil (i. e. how difficult it is to excavate etc.) Table 2.4 lists soil classes according to workability.

Table 2.4 Soil and rock classes according to VOB / C, DIN 18300 (DIN, 2009)

Classification of soil and rock Soil and rock are classified according to their condition when being worked on. Because it needs to be treated in a particular manner, topsoil is listed as an extra class regardless of its condition during excavation.
Class 1: Topsoil Top layer which contains – besides inorganic substances like mixtures of gravel, sand, silt, and clay – humus and soil organisms.
Class 2: Liquid soil Soil types of liquid to pasty consistency that barely release water.
Class 3: Easy to excavate Sands, gravels and sand-gravel mixtures consisting to a maximum of 15 % of silt and clay with particle sizes of less than 0.063 mm and to a maximum of 30 % of pebbles with particle sizes ranging from 63 mm to 200 mm. Organic soil types, which do not possess a liquid to pasty consistency, and peat.
Class 4: Moderately difficult to excavate Mixtures of sand, gravel, silt, and clay with respective minimum mass fractions of 15 % and a particle size smaller than 0.063 mm. Soil types with low to medium plasticity which possess, depending on water content, a soft to semisolid consistency and contain a maximum mass fraction of 30 % rock.
Class 5: Hard to excavate Soil types of the classes 3 and 4 with a rock mass fraction above 30 %. Soil types with a maximum mass fraction of 30 % blocks with a particle size ranging from 200 mm to 630 mm. Highly plastic clays which possess a soft to semisolid consistency, depending on the water content.
Class 6: Easy to excavate rock and similar soils Rock types which possess a minerally bound cohesion but are strongly fragmented, brittle, friable, slate, or weathered. Similar solid or solidified soil types created through dehydration, freezing or chemical bonding. Soil types with a block mass fraction above 30 %.
Class 7: Hard to excavate rock Rock types which possess a minerally bound cohesion and a high solidity, and which are slightly fragmented or weathered. Non-weathered argillaceous schist, conglomerate layers, solidified slags etc. Heavily packed/compacted great blocks with a particle size greater than 630 mm.

This concludes the remarks on geological questions. As shown, there are numerous material properties that may affect the calculation process. As a consequence, a definite weighting of these factors with the aid of expert literature is useful when handling individual cases. Furthermore, particular synergies are demonstrated in section 2.2.3.3.

2.2.3 Bases of calculation

Direct-cost calculations for partial activities are listed as separate contract items. In addition to these, percentage values of surcharges for site overhead, general overheads, as well as surcharges for risk and profit are added.

The direct costs can be broken down into the following cost types:

- Labor costs
- Equipment costs (incl. operating materials)
- Material costs
- Third-party / transport services
- Other general costs / costs for construction site facilities

Today, calculative modules are frequently employed in the construction engineering sector. These may be comprised of elements of single cost types, but hybrids of several cost types are also possible. These include maintenance and operating materials, expected idle periods such as setup times, maintenance, or technological downtimes etc.

When preparing the specific modules, an analysis of the single cost types together with affecting criteria is necessary. Regarding the preparation of the actual calculation of the items stated in the bill of quantities, these aspects are described below and later enter modules in the calculation examples that follow.

2.2.3.1 Calculation of labor costs

The calculation of personnel expenses involves labor costs for work performance in the form of average wage or several average wages according to profession groups or trades. In the following procedure, assessment is done in a company-specific way with the basic average wage as basis. The wage elements listed below have to be taken into account when calculating the average:

- Basic wage
- Additional payments (such as overtime, hazard pay, night shift etc.)
- Ancillary wage costs (such as accommodation allowance, fares, accommodation etc.)
- Social costs (such as social insurance, employer's liability insurance association etc.)
- Imputed costs (such as holiday pay, work safety etc.)

These wage elements result partially from legal regulations or from experiences / statistics of the particular company.

Possible wage increases also need to be considered for calculations of long-term projects. The example in the following section uses an average wage, which is calculated as shown in Table 2.5.

Table 2.5 Calculation of the average wage

Example equipment operator		
Wage element	**Surcharge**	**Portion**
Basic wage		15.70 €/h
Additional allowance	10 %	1.57 €/h
Ancillary wage costs	40 %	6.28 €/h
Social costs	60 %	9.42 €/h
Imputed costs	30 %	4.71 €/h
Average wage		**37.68 €/h**

2.2.3.2 Calculation of equipment costs

Calculation bases for equipment costs differ according to the specifications of every machine type. In Germany, the register of construction equipment published by the German construction engineering association, Hauptverband der Deutschen Bauindustrie e. V., serves as a standard. This register includes all groups of construction equipment and lists subgroups, equipment types, and sizes together with technical data (including expenditure of operating materials, operating life, consecutive operating life, and specific provision costs).

The provision costs of equipment can be subdivided into the costs for depreciation and interest (e. g. rental services) as well as repair costs (maintenance/upgrade) plus costs for service and upkeep. To calculate the abovementioned cost elements, the average value (average value when new) of the equipment serves as a basis according to the given (consecutive) operating life and the calculative rate of interest. Depreciation values listed in the register of construction equipment are applied using the linear method, and the repair costs are calculated as an average value over the span of operating life. In this context, it is assumed that the monthly usage of all equipment amounts to 170 hours.

Values for equipment that are missing in the register can be determined through interpolation of adjacent values. The stated repair costs in the register are given on a percentage basis and are the result of experience values.

For practical purposes, the values for depreciation and interest, as well as repair costs, are usually reduced to the market-based value of the particular country where the project is completed. Reductions are company-specific and can therefore not be generalized. A reduction on 60 % is assumed for the example in the following subsection. This value is often used for settlements in joint ventures where equipment costs are concerned.

Manufacturer information, which considers load, engine speed, operating condition and attrition, is used to assess consumption of operating materials. The register of construction equipment specifies a value of 80 to 170 [g/kWh] for fuel consumption, and 10 to 12 % of the fuel costs[50)] for consumption of lubricants. For the following example, the average consumption of this span is assumed.

Table 2.6 shows the calculation process of operating costs for a hydraulic excavator of 35 tons operating weight. The cumulative equipment costs are calculated under inclusion of a devaluation factor of 40 % and of all equipment modules and required additional equipment. The operating costs are comprised of the average wage for the machine operator and a surcharge of 10 % for maintenance and care as these are not included in the equipment costs.

Table 2.6 Calculation of operating costs for a hydraulic excavator of 30 tons

Hydraulic Excavator 35 t, 200 KW						
Registry entry number		**Av. new value**	**Rent (%/mo)**	**Rent (EUR/mo)**	**Repair (%/mo)**	**Repair (EUR/mo)**
D100 0200	Basic device	457,000.00	1.90 %	8,683.00	1.50 %	6,855.00
D100 0200 AA	Drive	12,700.00	1.90 %	241.30	1.50 %	190.50
D100 0200 AL	Hydraulic	12,400.00	1.90 %	235.60	1.50 %	186.00
D140 0200	Boom	72,000.00	1.90 %	1,368.00	1.50 %	1,080.00
D143 0200	Stem	31,900.00	1.90 %	606.10	1.50 %	478.50
D160 0300	Rock bucket	2,290.00	2.30 %	52.67	3.50 %	80.15
D160 0300 AD	Quick coupler	1,145.00	2.30 %	26.34	3.50 %	40.08
	Totals:	**589,435.00 €**		**11,213.01 €**		**8,910.23 €**
Operating years:	8					
Contingency time:	65 months					
Monthly rate:	1.90 %					
Service hours:	170 h/month					
Costs per hour of operation:				11,231.01 €/170h + 8,910.23 €/170h =		**118.48 €/h**
Depreciation factor (60 %):				118.48 €/h * 60 % =		**71.09 €/h**
Operating materials:						
80 to 170 g/KWh = Ø 125 g/KWh				(125g g/KWh/840 g/l) * 200KW * 1.10 €/l * 1.11 =		**36.34 €/l**
Handling:				Aver. wage 37.68 €/h * 1.1 (Maintenance and care factor) =		**41.45 €/h**
Total cost of equipment component excavator 35 t:						**= 148.88 €/h**

Based on this formula, it is possible to calculate any number of machine components and include them in the respective performance listings. Table 2.7 contains a number of equipment components that play a role in the following example calculation. The indicated average values are estimates taking into account ancillary equipment and any equipment elements as well as interpolations related to the performance variable.

50) Hauptverband der Deutschen Bauindustrie (2015), p. 15.

Table 2.7 Equipment summary earthworks

Calculation of equipment modules											
Assumptions: Consecutive operating life - 170 h / month Operating materials - 125 g / KWh, 0.84 kg / l, 11 % lubricants, diesel 1.10 € / l Service - average wage 37.68 € / h + 10 % maintenance + care = 41.45 € / h											
Item	**Pow-er [kW]**	**Equ.-Nr.**	**Av. New Value**	**Rent %**	**Rep. %**	**Monthly costs (60 %)**		**Conding-ency costs**	**Oper-ating material**	**Opera-tion**	**Total costs**
						Depr. / In-terests	**Rep.**				
Hydr.- Exca-vator 35 t	200	D1.00.0200	590,000.00 €	1.90 %	1.50 %	6,726.00 €	5,310.00 €	70.80 € / h	36.34 € / h	41.45 € / h	**148.59 € / h**
Hydr.- Exca-vator 72 t	300	D1.00.0300	1,020,000.00 €	1.90 %	1.50 %	11,628.00 €	9,180.00 €	122.40 € / h	54.51 € / h	41.45 € / h	**218.36 € / h**
Dozer (small)	78	D4.00.0078	300,000.00 €	3.20 %	3.10 %	5,760.00 €	5,580.00 €	66.71 € / h	14.17 € / h	41.45 € / h	**122.33 € / h**
Dozer (middle size)	140	D4.00.0138	480,000.00 €	3.20 %	3.10 %	9,216.00 €	8,928.00 €	106.73 € / h	25.44 € / h	41.45 € / h	**173.62 € / h**
Grader	120	D7.02.0118	363,000.00 €	2.90 %	2.70 %	6,316.20 €	5,880.60 €	71.75 € / h	21.80 € / h	41.45 € / h	**135.00 € / h**
Controls		Y0.60.0000	62,000.00 €	5.30 %	2.40 %	1,971.60 €	892.80 €	16.85 € / h	0.00 € / h	0.00 € / h	**16.85 € / h**
Roller 13 t	108	D8.31.1500	189,000.00 €	3.80 %	2.60 %	4,309.20 €	2,948.40 €	42.69 € / h	19.62 € / h	41.45 € / h	**103.76 € / h**
Roller 19 t	141	D8.31.1000	202,000.00 €	3.80 %	2.60 %	4,605.60 €	3,151.20 €	45.63 € / h	25.62 € / h	41.45 € / h	**112.70 € / h**

2.2.3.3 Equipment selection according to technical parameters

In order to carry out a calculation for earthworks, it is essential to choose appropriate equipment. In this respect, many influencing factors have to be considered, some of which are included in this section. An important factor in applied construction engineering is the optimal configuration and availability of equipment. Technical parameters of specific equipment dictate their possible assignment area, which is later included in the calculation.

The soil study and soil classes stated in the bill of quantities provide the basis for equipment selection. An essential condition for the utilization of equipment is that it possesses the required strength for excavation work and the required fragmentation and compaction parameters during filling procedures.

Depending on transport distances, various excavation equipment can be chosen. Bulldozers come into play at distances of up to 70 m for simultaneous removal and refilling of material. A wheeled loader performs similar functions for distances of up to 150 m and wheel tractor-scrapers perform at a transport distance of up to 250 m. In this case, an unobstructed transport route is required. When longer transport distances need to be covered, excavation and filling of soil material is done separately. This procedure usually involves an excavator as excavating and loading machine, suitable transport vehicles, and a bulldozer with rollers for compaction. Suitable transport vehicles, in this context, refer to vehicles that are capable of appropriately operating at construction sites and hold an optimum loading volume in proportion to the work cycles of the excavator.

Vehicle selection is, among other considerations, dependent on the type of road network (paved or unpaved), penetration depth of wheels, pitches, and rolling resistances. Dumpers are appropriate for rough terrain and shorter hauling distances of up to 2,500 m. For longer distances, trucks should be deployed, although they require a higher quality road network.

For a comparison of costs of individual vehicle types, it has to be taken into account that affecting variables are subject to fluctuation and change. Upgrading road networks to paved roads, for example, affects vehicle attrition and maximum transport speeds. Provided no items for this purpose exist in the contract, and the mass haul concept is created by the contractor, numerous variants for efficient road networks become feasible. In this case, costs for the creation and maintenance of construction roads are assigned to service items in the contract.

On-site soil types have a significant influence on the pricing of contract items. Particularly, conversion factors regarding soil parameters need to be taken into account. For instance, the ratio of density (gross density of stored material), bulk density (loosening when excavated in relation to soil type) and compacted density have to be considered. The performance values provided by manufacturers need to be adjusted accordingly for present soil types.

For optimum configuration of loading cycles, the local conditions of the construction site play a pivotal role. Optimization of loading height, loading angle, excavating depth and interdependencies of transport vehicles according to theoretical (i.e. calculated) criteria as well as employment of resulting manufacturer performance information can only be realized if present restrictions are insignificant and site conditions met.

If deviations from optimum site conditions occur, theoretical activities need to be reduced.

2.2.3.4 Material costs

Material costs are priced according to actual delivery costs. Suppliers provide quotations, which are priced in the actual contract. Any additional costs such as costs for freight, loading and unloading, intermediate storage or pre-financing have to be surcharged in the supplier quotations.

In the calculation example, material costs play a minor role. It is assumed that no material shortages may occur. Possible conversion factors have to be taken into account in case delivery materials are required in the calculation. Particularly, specific weight units play a major role since measurements are usually recorded in tons, whereas monetary compensation is based on volume.

2.2.3.5 External services / transports

Parallel to material costs, external services are calculated on the basis of actual delivery costs. The calculation involves costs for partial activities delivered by third-party companies. As a result, particular attention should be paid to the consistency of contractual conditions to avoid cost variance caused by different calculation bases.

Potential additional expenses for provision, supervision, and intersecting issues need to be imputed. Particular attention is therefore paid to transport services as they are frequently listed as ancillary services in the earthworks calculation. In general, transport costs have to be calculated according to particular cost types with due regard to technical parameters such as equipment modules. Alternatively, they can enter the calculation as external services. In this case, the different types of contract procedures must be taken into account. When a service rate that corresponds to the specifications of the service item is agreed on, the subcontractor price can be applied in the calculation. Prices for transport services that are offered as unfixed prices (i.e. an agreed amount, which may or may not increase due to difficulties that emerge during construction) occupy the same item positions as costs for equipment modules. On this basis, required transport capacities and corresponding transport costs per unit can be calculated.

In the following subsection, an example calculation for transport costs is given, which will be included in the earthwork calculation. Starting values for the calculation are the average transport distance, the average transport speed, the loading volume together with loading cycles, and work fees of transport vehicles. It is assumed that the average transport distance amounts to 5,000 m (one-way distance). This average is dependent on the quality of the road network on-site, ratio of inclination (slope), and the stated maximum speed on the site (as per site regulations). In the calculation example, a paved road network, neglectable slopes, and a maximum speed of 30 km/h are assumed. An empirical value of 70 % maximum speed for transport vehicles can be used as the average speed.

The parameters mentioned above are summarized in the following example. Based on this, the calculation of transport costs is illustrated. First, the length of the circulation (loading/unloading) period per transport vehicle is determined. The transport volume per vehicle and hour is the result of the average loading volume (keeping the loosening factor in mind). In order to ensure the scheduled loading capacity of the excavator, the required number of transport vehicles is determined. In a last step, the transport costs per quantity unit are calculated by dividing transport vehicle costs by the quantity transported per hour.

Example calculation of transport costs
Assumptions:

- Average one-way transport distance within the construction site: 5,000 m
- Road network = side roads of unbound base course, maximum permissible speed of 30 km/h on the site, 70 % = 21 km/h transport speed
- Loading capacity Cat 365 = 250 m³/h, loading volume of four-axle truck: 8 m³ solid mass, loosening factor: 0.25 → 10 m³ loose mass, loading time including transition time 3 min., unloading time 2 min.
- Offered hourly rate four-axle truck = 50.00 €/h

Calculation:

Circulation time:

3 min loading + 2 min unloading + 28.57 min driving (2 x 5,000 m/350 m/min)

= 33.57 min.

Quantity per truck and hour:

60 min/33.57 min = 1.79 loads/h x 8 m³/load = 14.32 m³/h

Number of trucks:

250 m³/h loading capacity/14.32 m³/h transport capacity per truck = 17.46 = 18 trucks

Transport costs per quantity unit:

(18 trucks x 50.00 €/h)/250 m³/h loading capacity **= 3.60 €/m³**

2.2.3.6 Other expenses/costs for construction site facilities

Overheads are costs that do not fit any category of the abovementioned cost types. In construction projects, these are miscellaneous costs that are not related to a particular service item directly and are, as a consequence, spread among several items.

The costs for construction site facilities, capacity costs (cost of capacity that may be used), and post-construction site-cleaning operations are therefore calculated in an additional bill of quantity. Costs such as the expenses for delivery and return of equipment are included in these items.

Additional expenses are added in the calculation on a percentage basis. These include general overheads, which are not directly related to the construction site like costs for administration/management, as well as site overheads, which are relevant for the whole project, as well as labor costs of the site management. Cost planning for general overhead provides estimates for major cost items in relation to the contractor's turnover (overhead expenses) and project turnover (site overheads). Further calculated percentage surcharges for risk and profit are also included in the calculation.

In the calculation example, the following hypothetical general expenses are used:

General overheads 8 %, site overheads 6 %, risk 3 %, and profit 3 %; the sum of the surcharges amounts to 20 %.

2.2.3.7 Analysis of the complete project

The calculation of earthwork items of large scale projects should never be treated in isolation but all contractual tasks/activities must be considered, including all earthwork items. As a result, potential synergy effects between construction-related tasks can be recognized and utilized more easily.

Furthermore, it is essential during the estimation process to get an overview of all stipulated contract conditions and to take them into account. These conditions involve, in particular, the construction specifications, guidelines to specific sections, subsoil studies, additional technical specifications, contractual deadlines, and standards described in the planning license/construction permit.

Supplementary work to be included, such as provisional deadlines, possible synergies with construction tasks of other construction lots, access regulations to the site, working time arrangements, or effects on local residents, are a result of the conditions mentioned above.

The general contract conditions, therefore, provide the main framework for the calculation of the partial activities stipulated in the particular service items.

2.2.4 Preparatory work, systematization of the earthwork engineering services

Contract documents likely include only general information about the earthworks. The precise planning and optimization is left to the contractor's devices. Consequently, preparatory work and optimization of work processes already play a major role in the estimation process.

Particularly, these steps involve the examination of the quantity record specified in the contract, the preparation of a mass haul diagram with identified average transport distances, and the preparation of a construction schedule.

In the course of the examination of the quantity record, not only the strict revision of material consumption and surplus is of importance, but the possibility of optimizing utilization of soil masses needs to be considered. Not every type of soil, for example, is suitable to create a planum layer for road construction because attributes such as plasticity and granulation may be suboptimal. As a consequence, required partial qualities need to be considered for the specific creation of a planum layer.

A mass haul diagram visualizes the masses to be excavated and reintegrated on the site via a mass-distance-diagram. An example of a simple mass haul diagram, without allocated fill areas, is shown in Figure 2.7.

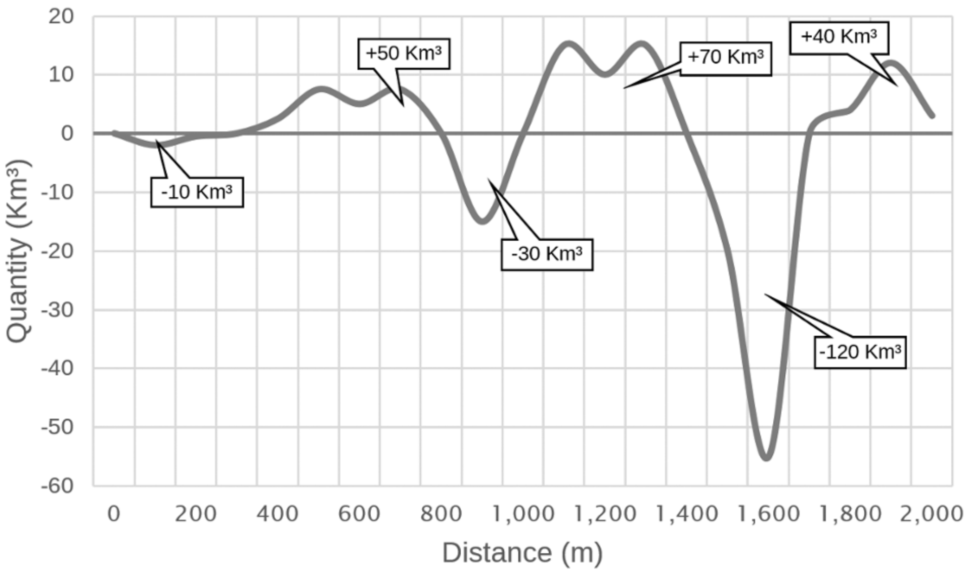

Figure 2.7 Example for a mass haul diagram

Allocation of excavated masses to the various filling areas is regularly updated by the contractor. For this purpose, non-specific margin conditions are given in the contract such as the integration of soil replacement materials into given disposal sites of the client. The average transport distance is determined through the prepared allocation of excavation and filling areas.

If necessary, this distance has to be calculated separately for the different partial earthwork items to precisely identify actual costs for specific items.

Construction-schedule preparations for the entire construction project are tied to the calculation bases of the earthworks, because the factors' time and synergies with other construction tasks have to be considered for the mass haul diagram. Deployment of an intermediate storage unit for partial quantities, for instance, is a possibility.

2.2.5 Corresponding factors of construction execution

As already outlined in the preceding section, various factors need to be observed in the estimation process. These factors generate interdependencies among each other and may only be examined in their entirety.

To illustrate synergies relating to earthworks, framework conditions, construction schedule, mass haul diagram, and equipment schedule will be outlined briefly in the following section.

As mentioned above, specifications provided by the client, such as contractual intermittent deadlines and the adjustment of parallel construction tasks have to be included in the construction schedule. Processing times for specific tasks can be defined via selected calculation approaches.

An essential cost factor of the mass haul diagram is the average transport distance, which needs to be minimized for efficiency. Here, the limiting factor is the optimized utilization of available soil with associated longer transport distances that may become inevitable. The main goal is to avoid intermediate storage sites.

Moreover, the use of equipment cannot be limited to specific service items. It is necessary to choose equipment for the whole of the construction project and to minimize capacity costs by avoiding unproductive periods. A precondition for ideal equipment operation is their availability. Renting required equipment on the free market is an option, but usually leads to higher capacity costs. As a consequence, equipment modules need to be reviewed accordingly.

The specific margin conditions, mass haul diagram and equipment schedule may coincide and affect each other. Quantity and capacity of included equipment result in a minimum construction time for the realization of all tasks. This minimum construction time must directly relate to the margin conditions of the construction schedule in such a way that all processes can be finished on time.

Utilization and distribution of soil masses affects both task duration and equipment selection. It is therefore possible to convert present masses into higher-quality materials and hence minimize third-party deliveries of higher-value materials and disposal of excess material.

A general approach to handle this problem does not exist as yet, as all factors may vary in numerous ways, and different corporate philosophies in relation to equipment procurement and the vertical range of manufacture need to be taken into account.

2.2.6 Calculation of the partial activities

2.2.6.1 Preliminary remarks

After detailed preliminary considerations and an outline of the basic influencing factors were given in the preceding sections, the final economic calculation of the earthworks is presented in the following part of this chapter. It is possible to envision the final calculation schematically now that cost components such as labor costs, equipment, and transportation costs have been determined and technical factors, as well as performance parameters, have been described. In order to calculate partial activities, it is essential to assess the coverage of calculated items. Listed services in the contract need to be identified, and it has to be established which services that enter the calculation result from preliminary remarks, specifications, geotechnical studies etc. Moreover, it is important to understand which additional services result from contractual terms and conditions and which accounting procedures are predefined.

Once the aforementioned is established, a definition follows of how the services are to be calculated, what kind of technology, equipment, and performance approach for construction tasks are to be used. Furthermore, a classification of cost components for each item is required. Hence, fixed cost components, such as delivery and return transports, are included in the items site facilities and post-construction site cleaning.

In case several positions are occupied in parallel, synergies with other positions should be examined so that, for example, empty trips are avoided.

The type of calculation also has to be determined. For common positions, adjustable calculations with performance approaches are usually employed. Smaller performance positions or additional services fare better with a fixed-cost determination of the cumulative effort and subsequent distribution to total performance (for example, ensuring availability of a water truck for the period of mass transportation for dust control on construction roads).

2.2.6.2 Calculation examples

A fictitious bill of quantity for the examples in the next part of the chapter is shown in Table 2.8 below. The calculation is schematically developed.

Table 2.8 Bill of quantities earthworks

Item	Text	Quantity	Unit
01.01	**Earthworks**		
01.01.10	**Topsoil removal and storage**	10,000.00	m³
	Remove and store topsoil growth. Thickness of 10 to 30 cm. Sowing and reaping of topsoil plant mass compensated separately. Transport and store topsoil within site, separate rocks and roots. Pile topsoil in consistently shaped, loose heaps. Compensation according to removed-quantities profile.		
01.01.20	**Covering topsoil of client**	8,000.00	m³
	Cover stored topsoil of client according to profile. Provide cover on slopes, troughs etc. Thickness of cover ca. 10 to 20 cm. Gather and transport stored topsoil within site. Compensation according to added-quantities profile.		

01.02.10	**Excavation and reintegration of soil and rock**	100,000.00	m³
	Excavate and reintegrate soil and rock respectively in designated areas according to profile. Produce class 3 to class 6 soil within site. Mass distribution responsibility of contractor. Creation of troughs and trenches compensated separately. Creation of planum layer not compensated separately. Compensation according to re-moved-quantities profile.		
01.02.15	**Bonus for excavating soil and rock**	25,000.00	m³
	See previous item, addition of bonus payments for class-7 soil. Fill local depressions, emerging during rock removal, with suitable, frost-resistant material. Creation of planum layer not compensated separately. Compensation according to removed-quantities profile.		

The calculation is done in three steps:

1. Determining the scope of construction works
2. Selection of technology
3. Calculation of direct costs

Item 01.01.10: Topsoil removal and storage

The Item 01.01.10 covers the following services:

- Material removal and storage
- Material transportation
- Material separation
- Making material heaps and creating profiles

For the choice of technology, the assumption is made that topsoil is uniformly distributed in the construction field, and storage along the marked-out route is possible. The chosen *technology* and the cost elements are as follows:

- Removal + transport with caterpillar dozer (140 kW), material such as soil distributed in heaps along route.
- Compacting storage heaps with excavator (35 t).
- Separation (sorting out rocks and roots) is counted as synergy in item 01.01.20 because it is possible to perform simultaneously with loading process.
- The determined sliding length is 50 m, heap height is 2 m.
- Compacting of storage heaps is calculated via capacity approach in m² and allocated according to the item's unit of measurement. The quantity in m² results from the cross-section of the heaps.
- (Height/wdth 2 m, 1/1 sloped; 8 m³ each running meter with approx. 7.7 m² each running meter; 10,000 m³/8 m³ x 7.7 m² = approx. 9,625 m²).

– Capacity approach (value derived from experience or manufacturer information with regard to local conditions) for caterpillar 100 m^3/h, for excavators 150 m^2/h, cost of equipment module caterpillar 173.62 €/h, excavators 148.59 €/h.
– Fixed costs of transport equipment delivery and return are included in site facilities/post-construction cleaning .
– General overheads, including risks and profit, of 20 %.

Under the mentioned conditions, the *direct costs* are determined as follows:

– Portion of caterpillar (load + transport + setup): 173.62 €/h/100 m^3/h	1.74 €/m^3
– Portion of excavator (Heap compacting): 148.59 €/h/150 m^2/h = 0.99 €/m^2 x (9,625 m^2/10,000 m^3)	0.95 €/m^3
The direct costs for the item hence amount to:	**2.69 €/m^3**

Following the same pattern, the following additional items are calculated, partially, with deviating assumptions, to illustrate a wide range of calculations.

Item 01.01.20 Covering topsoil of client_

Scope of services:

– Separating material (from item 01.01.10)
– Loading material
– Transporting material to the site
– Piling and compacting material according to stated profile

Technology and considered cost components:

– It is assumed that the loading into separating equipment with feeder onto transporting vehicle as external service of 5.00 €/m^3, at the same time assuming that the density of the stored material = density of covered material due to compensation according to added-quantity profile, otherwise consideration of special compensation agreement with third-party service and conversion factor have to be taken into account
– Transport to site likewise as external service, assumed 2.00 €/m^3
– Piling with excavator 35 t and a capacity of 50 m^3/h
– Surveying material (to adapt slopes) for covering according to profile is calculated as expected fixed cost of site preparation. The surveying performance is part of surcharges for site overheads

Determination of direct costs:

– Portion of third-party load. + separating service	5.00 €/m^3
– Portion of third-party transport service	2.00 €/m^3
– Portion of excavator for compacting: 148.59 €/h/50 m^3/h	2.97 €/m^3
Total direct costs:	**9.97 €/m^3**

Item 01.02.10 Excavation and reintegration of soil and rock

Scope of services:

- Excavation and loading of material according to profile
- Transporting material to designated reintegration site
- Reintegration and compacting of material according to profile
- Creation of planum layer

Technology and considered cost components:

- Loading with excavator 300 kW and assumed capacity of 250 m³/h, surveying material for excavation according to profile in construction-site facilities, include surveyor in site overhead calculations
- Transport to site similar to calculated example in section 2.2.3.5: 3.60 €/m³
- Reintegration with dozer 140 kW, 250 m³/h, and two rollers 19 t for compacting
- Preparing planum layer with grader + controller and roller 13 t for compacting, assumed capacity of 200 m²/h and assuming that 20.000 m² planum layer accumulate for this capacity; this means that this capacity with a factor 20,000 m²/100,000 m³ = 0.2 is included in the item

Determination of direct costs:

– Rate of excavator for exc. + load. 218.36 €/h/250 m³/h	0.87 €/m³
– Rate of transport	3.60 €/m³
– Rate of reintegration (173.62 €/h +2 x 112.70 €/h)/250 m³/h	1.60 €/m³
– Rate of planum layer creation (135.00 + 16.85 + 103.76) €/h/200 m²/h x 0.2 m²/m³	0.26 €/m³
Total direct costs	**6.33 €/m³**

Item 01.02.15 Bonus for excavating soil and rock

Scope of services:

- Bonus position means that the price of the basic position (here 01.02.10) will be compensated and the excavation of deviating soil types is compensated additionally e. g. allowance for the loosening of soil class 7, by blowing or mechanical processing
- Allowance for the filling material for the creation of the planum layer
- Provide suitable frost resistant material, external supply is not required, the material must be separated from the ablation areas, temporarily stored and transported to the site
- Additional expenses for the preparation of the planum layer

Technology and considered cost components:

- It is assumed that the material can be demolished, explosive grid is chosen that an extra mechanical treatment is not necessary
- It is assumed that the material is calculated as external service of 3.00 €/t at a conversion factor 2.0 t/m³ = 6.00 €/m³, as it is assumed to be cheaper than separation and temporary storage of material from the site

– Allowance planum preparation with graders + controlling and roller 13t for compacting. It is assumed that there is an allowance for halving the capacity to 100 m²/h because of material transfers and the assumption that 5,000 m² planum arise for this item; this means that this service goes into this item with a factor of 5,000 m²/25,000 m³ = 0.2

Determination of direct costs:

– Rate of external blowing service 6.00 €/m³
– Rate of material delivery
5,000 m² x 0.10 m str x 6.00 €/m³/25,000 m³ 0.12 €/m³
– Rate of planum allowance
(135.00 + 16.85 + 103.76) €/h/100 m²/h x 0.2 m²/m³
– 0.26 €/m³ (from main position) = 0.25 €/m³

Total direct costs **6.37 €/m³**

2.2.7 Conclusion

After all the positions are calculated, the overprinted bill of quantities with the total price can be prepared. Table 2.9 shows the resulting bill of quantities with short texts.

Table 2.9 Short text - bill of quantities with prices

Item	Text	Quantity	Unit	Direct costs	Sur-charge (€/m³)	Unit Price (€/m³)	Total Price (€)
01.01.	**Earthworks**						
01.01.10	Topsoil remove and store	10,000.00	m³	2.69	0.54	3.23	32,280.00
01.01.20	Covering top soil of the client	8,000.00	m³	9.97	1.99	11.96	95,712.00
01.02.10	Soil and rock loosening and installing	100,000.00	m³	6.33	1.27	7.60	759,600.00
01.02.15	Allowance loosen for soil and rock	25,000.00	m³	6.37	1.27	7.64	191,100.00
Total							**1,078,692.00**

The calculation has primarily been shown in economic terms. Cost types, cost elements and calculation methods have been declared and can schematically serve as an example for earthworks calculations.

Technical influencing factors were nominated. Empirical values of the contractor have been used for the calculation.

Due to the influence of many variables, a fixed method of calculation is not reasonable. Rather, possible variable factors were nominated and interdependencies identified. It was outlined that soil conditions, as well as spatial and temporal characteristics of the site can theoretically change the performance approaches greatly. For further reading, advice provided by the device manufacturer is recommended. The importance of equal rank for the calculation of earthwork services is the consideration of the overall project, along with extensive preparatory work, even in the calculation phase. Only then can appropriate technologies for the overall success be found and synergies between various service positions used. For this purpose, various factors have to be considered.

2.3 Estimating in road construction

The bid preparation in road construction is conducted on the basis of a public or private client bid. In the following section, the key components of a request for proposal are initially explained. In upcoming sections, the fundamentals of calculation are illustrated with the aid of an exemplary road construction project.[51)]

Most commonly, bid documents include, but are not limited to, the following parts:[52)]

- An invitation to bid
- Terms and conditions for the application and execution of construction services in road and bridge construction of the European Union (Edition: March 2012)
- Bid letter
- Special contract conditions
- Additional contractual terms and conditions for the execution of construction services in road and bridge construction[53)]
- Specifications for bids

According to the above mentioned framework, the invitation to tender or call for bids includes, but is not limited to, the following important basic information for the contractor:

- Contracting authority
- Type of bid (e. g. public invitation to tender, restricted invitation to tender)
- Notation of the construction services
- Information on the bidding process (e. g. submission conditions)
- Admission of variant solutions
- Criteria for the bid valuation

The additional terms and conditions primarily comprise deadlines, possible contractual penalties and payments for acceleration measures as well as limitation periods for claims on defects.

2.3.1 Construction specifications

The most important element of the specifications of services should be the construction specifications.

51) In the German construction practice, particularly public clients utilize the "Handbuch für die Vergabe und Ausführung von Bauleistungen im Straßen- und Brückenbau (HVA B-StB)" (translation: Handbook for the Allocation and Execution of Construction Projects for Road and Bridge Construction), which includes guidelines and samples for the preparation of bids.

52) BMVI (2012).

53) "Zusätzliche Vertragsbedingungen für die Ausführung von Bauleistungen im Straßen- und Brückenbau (ZVB / E-StB 2012)".

In the construction specifications, a general description of the construction assignment needs to be included. It includes all object-related data, requirements, and conditions, which are necessary to describe the activity in addition to the "bill of quantities". This description is thereby helpful for a better understanding of the details of the partial activities[54]. Additionally, it includes a bill of quantity which, in particular, is composed of items describing the requested services. In road construction the contracting authority usually chooses items from the standard service catalog for road and bridge construction by the Road and Transportation Research Association (FGSV).

The specifications stated in the invitation to tender, including particular regulations, need to be considered in the bid preparation.

2.3.2 Direct costs of the partial activities

In consideration of the overall construction project, the construction methods for the calculation of an item should be specified to comply with the item description. If, for example, a frost protection layer needs to be created in the area of a driveway, the installation is usually done with an excavator and the compaction with a surface vibrator. However, when a large quantity of frost protection material is to be installed on a long route with an adequate width, the utilization of a grader with a drum compactor becomes more economically advantageous, because this equipment combination can reach a much higher performance. After the definition of the relevant construction method, the direct costs of the partial activities per item, which can be composed of the following cost types, are calculated.

Labor costs
Construction companies calculate actual average wages per professional group (road worker, machine operator, etc.) from their basic wages, overtime bonuses, ancillary wage costs, and social costs. In the following calculation example a consistent average wage of 35 €/h is assumed.

Material costs
This refers to the costs for material that is delivered to the construction site (e.g. tarmac, bulk material, sewer material). It is assumed that the material price already includes the transport costs to the construction site. These prices need to be requested from the suppliers prior to calculation.

Equipment costs
Construction firms determine the capacity costs for their equipment based on the register of construction equipment. Capacity costs together with the costs of operating supplies result in the overall plant cost.

External services
These services could involve: subcontractor services, disposal or recycling costs, transport costs including costs of operating supplies, and operation. These prices also need to be requested from external firms prior to calculation.

54) in German: Bundesministerium für Verkehr, Bau und Stadtentwicklung, Abteilung Straßenbau: Handbuch für die Vergabe und Ausführung von Bauleistungen im Straßen- und Brückenbau (HVA B-StB), 2012.

In the calculation of road construction, labor and equipment costs are based on performance approaches per quantity unit. The performance approaches are usually dependent on given amounts of experience.

2.3.3 Overheads and other surcharges

The direct costs of the partial activities are finally surcharged with additions for general overheads, site overheads and for risk and profit.

In this calculation example the following apportionments are assumed:

12 % general overheads + 5 % site overheads + 1.5 % risk + 1.5 % profit = 20 %

2.3.4 Calculation example

2.3.4.1 Construction specifications

A. General description of the construction project

Because of the high congestion on the federal road B 999 in Sample City, a bypass is created. The lane of traffic corresponds to the load class 3,2 according to RStO (Richtlinien für die Standardisierung des Oberbaus - Edition 2012). It has a length of 2,000 m and is built with a regular width of 7.50 m in accordance with standard cross-section RQ 10,5.

The earthworks, as well as the connections to the existing B 999, have already been completed. The initial surface is raw subgrade (+/- 5 cm) executed in the scope of the preliminary work. A fine subgrade should initially be created. Subsequently, the superstructure has to be fabricated:

- 4 cm asphalt surface AC 11 D S 25/55–55
- 6 cm asphalt binder layer AC 16 B S 25/55–55
- 12 cm asphalt base layer AC 32 T S 50/70
- 43 cm frost protection layer 0/32
- 65 cm superstructure

Additionally, the road shoulders need to be created. On the already constructed connections to the B 999, the existing asphalt surface needs to be stripped down by 4.0 m in each case. The road equipment and traffic safety measures are not part of this measurement.

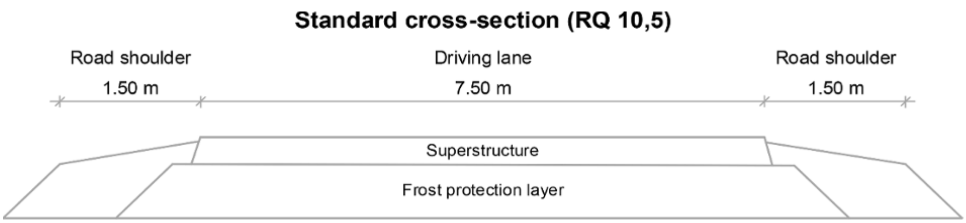

Figure 2.8 Schematic road design

B. Details of the construction site

The site is situated to the west of a fictional city and can only be accessed by car from the north or south via the existing B 999.

C. Details of the execution

The work is carried out outside traffic hours. The construction site's entrances and exits are marked by a third-party contractor.

2.3.4.2 Bill of quantities

Table 2.10 consists the particular items without prices.

Table 2.10 Bill of quantities B999 without prices

Item	Text	Quantity	Unit
1.	**Preliminary works**		
1.1.	**Excavation works**		
1.1.10	**Asphalt milling and up-load**	60.00	m²
	Milling depth 4 cm. Recycle the arising milled material of recycling classification A (choice of the contractor). The surface needs to be cleaned.		
1.1.20	**Detach asphalt pavement**	45.00	m
	Straightforward detachment of the asphalt pavement, Strength of 4 to 12 cm.		
1.2.	**Earthworks**		
1.2.10	**Create subgrade**	21,000.00	m²
	Creation of a subgrade with a maximal deviation of +/- 2 cm from the specified level. E-Modulus EV2 = 45 MN/m².		
1.2.20	**Load and recycle material**	600.00	m³
	Loading and recycling of the remaining material arising from the profiling of the subgrade (choice of the contractor).		
1.2.30	**Create soil improvement**	21,000.00	m³
	Mechanical blending, grading and compaction of soil and scattered binder material (Portland cement with 25 kg/m²). Thickness of the improved layer: 25 cm.		

Item	Text	Quantity	Unit
2.	**Superstructure**		
2.1.	**Layers without binder material**		
2.1.10	**Create frost protection layer**	7,500.00	m³
	Installing and compaction of frost protection material with a 0/32 grain size. Layer thickness 43 cm. EV2 min: 120 MN/m²		
2.1.20	**Create road shoulders**	4,000.00	m
	Creation and compaction of road shoulders with a width of 1.50 m and total strength of 52 cm. Delivery and installation of compactable soil for the 32 cm bottom layer. In the upper 20 cm top layer, a gravel terrace composite with a grain size of 0/32 is to be installed.		
2.2.	**Asphalt constructions**		
2.2.10	**Install asphalt base layer**	15,000.00	m²
	Creation of an asphalt base layer from AC 32 TS 50/70. Thickness 12 cm.		
2.2.20	**Install asphalt binder layer**	15,000.00	m²
	Creation of an asphalt binder layer from AC 16 BS 25/55–55 A. Thickness 6 cm.		
2.2.30	**Install asphalt surface**	15,000.00	m²
	Creation of an asphalt surface from AC 11 D S 25/55–55 A. Thickness 4 cm.		
2.2.40	**Spray on bituminous binder**	30,000.00	m²
	Spraying on of binder C 60 BP1-S with 200 g/m² on traffic surface.		
2.2.50	**Blunt measure**	15,000.00	m²
	Scattering and rolling-in of spreading grit with a grain size of 1/3. Density 1 kg/m². Removal and recycling of the loose material at choice of the contractor.		

2.3.4.3 Calculation of the partial services

1.1.10	**Asphalt milling and upload**	60.00	m³
	Milling depth 4 cm. Recycle the arising milled material of recycling classification A (choice of the contractor). The surface needs to be cleaned.		

Selection of technology

<u>A. Asphalt milling and upload</u>

The milling and uploading of the asphalt is done with a milling machine (200 €/h). The milling performance is estimated at only 30 m²/h due to the small size of the milled area. The complete service of 60 m² is therefore performed in 2 h. Costs for the machine operator are included in the labor costs.

<u>B. Material recycling</u>

The milling material is loaded on a truck with a loading capacity of 12 tons (50 €/h including operator) and can, for example, be recycled in a mixing plant (recycling costs = third-party costs of 2 €/t). First, the transport costs need to be ascertained. In the calculation of the loading time, the time of 2 hours = 120 minutes required for the milling of the surfaces, has been taken into account.

Calculation of the transport costs:

+ loading time on site	120 min
+ transport time to the recycling plant 20 km: 40 km/h	30 min
+ unloading time	20 min
Sum = cycle	**170 min**
Hours	**2.83 h**

The surface area of 60 m² results in a mass of 60 m² x 0.04 m x 2.5 t/m³ = 6 t which has to be recycled. This has to be taken into account in the calculation.

<u>C. Surface cleaning</u>

The cleaning of the surface should be done by a wheel loader with an attached suction sweeper (40 €/h). This process occurs directly after the milling procedure and is therefore estimated to have the same performance (30 m²/h). As in the previous process, the machine operator is considered in the labor costs.

Calculation

Labor		
2 x 35 €/h/30 m²/h		2.33 €/m²
Material		
–		
Equipment		
(200 €/h + 40 €/h)/30 m²/h		8.00 €/m²
External services		
Transport:	0.100 t/m² x 2.83 h/circulation x 50 €/h/ 6 t/circulation	2.36 €/m²
Recycling:	0.100 t/m² x 2 €/t	0.20 €/m²
Sum of direct costs		12.89 €/m²
Overheads (20 %)		2.58 €/m²
Unit price		**15.47 €/m²**

1.1.20	**Detach asphalt pavement**	45.00	m
	Straightforward detachment of the asphalt pavement, Strength of 4 to 12 cm.		

Selection of technology

The split cut is carried out by a craftsman with a joint cutter (7.50 €/h). A performance of 10 m/h is assumed.

Calculation

Labor	
1 x 35 €/h / 10 m/h	3.50 €/m
Material	
–	
Equipment	
7.50 €/h/10 m/h	0.75 €/m
External services	
–	
Sum of direct costs	4.25 €/m
Surcharges (20 %)	0.85 €/m
Unit price	**5.10 €/m**

1.2.10	**Create subgrade**	21,000.00	m²
	Creation of a subgrade with a maximal deviation of +/- 2 cm from the specified level. E-Modulus EV2 = 45 MN/m².		

Selection of technology

In this case, the application of a grader (60 €/h) is efficient as the surface area is bigger. To achieve the required deformation module, the surface has to be compacted with the aid of a barrel compressor (30 €/h). Both machines are handled by one operator each. A performance of 400 m²/h is calculated.

Calculation

Labor	
2 x 35 €/h/400 m²/h	0.18 €/m²
Material	
–	
Equipment	
(60 €/h + 30 €/h)/400 m/h	0.23 €/m²
External services	
–	
Sum of direct costs	0.41 €/m²
Surcharges (20 %)	0.08 €/m²
Unit price	**0.49 €/m²**

1.1.20	**Load and recycle material**	600.00	m³
	Loading and recycling of the remaining material arising from the profiling of the subgrade (if wanted by the contractor).		

Selection of technology

The excess material is loaded by an excavator (40 €/h) which is handled by a machine operator. A third-party contractor recycles the material (costs for recycling including transport costs: 7.50 €/t). Recycling costs are usually offered by subcontractors in the quantity unit ”ton”. In this case a conversion into the appropriate quantity unit ”m³”, with regard to the expected density in the built-in condition (here 2.1 t/m³), has to be included in the calculation.

Calculation:

Labor	
1 x 35 €/h/30 m³/h	1.17 €/m³
Material	
–	
Equipment	
40 €/h/30 m³/h	1.33 €/m³
External services	
2.1 t/m³ x 7.50 €/t	15.75 €/m³
Sum of direct costs	18.25 €/m³
Surcharges (20 %)	3.65 €/m³
Unit price	**21.90 €/m³**

1.2.30	**Create soil improvement**	21,000.00	m³
	Mechanical blending, grading and compaction of soil and scattered binder material (Portland cement with 25 kg/m^2). Thickness of the improved layer: 25 cm.		

Selection of technology

The embedding of the binding material is done with a rotary cultivator (150 €/h), the leveling with a grader and the compaction with a barrel compressor as used in item 1.2.1. Plants are handled by one machine operator each. Additionally, the calculated amount of Portland cement, with an offering price of 90 €/t, has to be added. There must also be a conversion from the offered material costs into the appropriate quantity unit.

Calculation

Labor	
3 x 35 €/h/300 m²/h	0.35 €/m²
Material	
25 kg/m²/1000 kg/t x 90 €/t	2.25 €/m²
Equipment	
(150 €/h + 60 €/h + 30 €/h)/300 m²/h	0.80 €/m²
External services	
–	
Sum of direct costs	3.40 €/m²
Surcharges (20 %)	0.68 €/m²
Unit price	**4.08 €/m²**

2.1.10	**Create frost protection layer**	7,500.00	m³
	Installation and compaction of frost protection material with a 0/32 grain size. Layer thickness 43 cm. EV2 min: 120 MN/m^2.		

Selection of technology

The material installation is completed with a grader and the compaction is, again, done with the previously mentioned barrel compressor. The price for the frost protection material (10 €/t) has to be converted into the appropriate quantity unit "m³".

Calculation

Labor	
2 x 35 €/h/40 m^3/h	1.75 €/m³
Material	
2.1 t/m³ x 10 €/t	21.00 €/m³
Equipment	
(60 €/h + 30 €/h)/50 m^3/h	1.80 €/m³
External services	
–	
Sum of direct costs	24.55 €/m^3
Surcharges (20 %)	4.91 €/m³
Unit price	**29.46 €/m³**

2.1.20	**Create road shoulders**	4,000.00	m
	Creation and compaction of road shoulders with a width of 1.50 m and a total strength of 52 cm. Supply and installation of compactable soil for the 32 cm bottom layer. In the 20 cm top layer, a gravel terrace composite with a grain size of 0/32 is to be installed.		

Selection of technology

The installation and compaction of the road shoulders is done by a subcontractor for road shoulder work, which offers the stated services with a price of 1.50 €/m. Subcontractor services are external services. Furthermore, the supply of compactable soil (5 €/t) and the gravel terrace composite with a grain size of 0/32 (12.50 €/t) need to be calculated.

Calculation

Labor

–

Material

Bottom layer: 1.50 m x 0.32 m x 2.0 t/m³ x 5 €/t	4.80 €/m
Top layer: 1.50 m x 0.20 m x 2. 0 t/m³ x 12.50 €/t	7.50 €/m

Equipment

–

External services

Subcontractor for road shoulder work	2.50 €/m
Sum of direct cost	14.80 €/m
Surcharges (20 %)	2.96 €/m
Unit price	**17.76 €/m**

2.2.10	**Install asphalt base layer**	15,000.00	m²
	Creation of an asphalt base layer from AC 32 TS 50/70. Layer thickness 12 cm.		

Selection of technology

The asphalt is mechanically applied with an asphalt finisher (200 €/h) in large areas. Recompaction of the installed material is done using two tandem rollers (40 €/h). Usually, the asphalt finisher equipment additionally consists of small equipment, such as, joint cutters, various chains, etc., whose costs are calculated at a 10 €/h rate. For the operation of the finisher equipment, five machine operators are required (one engine driver, two machinists for the handling of the paving screed, and two roller drivers). The delivery of the asphalt mixes is calculated as material costs. When working with asphalt mixes the delivery and also the definition of the installation performance is usually performed using the quantity unit ”ton”. As a consequence, a conversion from ”tons” into the appropriate quantity unit ”m²” is necessary. The density of the asphalt mix is used as the conversion factor. This value is ascertained via laboratory testing and is represented by the so-called Marshall density. In this case, the wide-spread density of 2.50 t/m³ is chosen.

Calculation

Labor

0.12 m x 2.50 t/m³ x 5 x 35 €/h/100 t/h	0.53 €/m²

Material

0.12 m x 2.50 t/m³ x 45 €/t	13.50 €/m²

Equipment

0.12 m x 2.50 t/m³ x (200 €/h + 2 x 40 €/h + 10 €/h)/100 t/h	0.87 €/m²

External services

–

Sum of direct costs	14.90 €/m²
Surcharges (20 %)	2.98 €/m²
Unit price	**17.88 €/m²**

2.2.20	**Install asphalt binder layer**	15,000.00	m²
	Creation of an asphalt binder layer from AC 16 BS 25/55–55 A. Thickness 6 cm.		

Selection of technology

Analogous to the previous item 2.2.10

Calculation

Labor	
0.06 m x 2,500 t/m³ x 5 x 35 €/h/75 t/h	0.35 €/m²
Material	
0.06 m x 2,500 t/m³ x 60 €/t	9.00 €/m²
Equipment	
0.06 m x 2,500 t/m³ x (200 €/h + 2 x 40 €/h + 10 €/h)/75 t/h	0.58 €/m²
External services	
–	
Sum of direct costs	9.93 €/m²
Surcharges (20 %)	1.99 €/m²
Unit price	**11.92 €/m²**

2.2.30	**Install asphalt surface**	15,000.00	m²
	Creation of an asphalt surface from AC 11 D S 25/55–55 A. Thickness 4 cm.		

Selection of technology:

Analogous to the previous item 02.01.10

Calculation:

Labor	
0.04 m x 2,500 t/m³ x 5 x 35 €/h/50 t/h	0.35 €/m²
Material	
0.04 m x 2,500 t/m³ x 80 €/t	8.00 €/m²
Equipment	
0.04 m x 2,500 t/m³ x (200 €/h + 2 x 40 €/h + 10 €/h)/50 t/h	0.58 €/m²
External services	
–	
Sum of direct costs	8.93 €/m²
Surcharges (20 %)	1.79 €/m²
Unit price	**10.72 €/m²**

2.2.40	**Spray on bituminous binder**	30,000.00	m²
	Spraying on binder C 60 BP1-S with 200 g/m^2 on traffic surface.		

Selection of technology:

The bituminous binder is sprayed on the asphalt base layer as well as on the binder layer to ensure an adhesion with the overlying layer. The spraying of such large areas is done with so-called spray bars (25 €/h). The material C 60 BP1-S is calculated with 700 €/t.

Calculation

Labor	
1 x 35 €/h/500 m²/h	0.07 €/m²
Material	
0.200 kg/m^2/1000 kg/t x 800 €/t	0.16 €/m²
Equipment	
25 €/h/500 m^2/h	0.05 €/m²
External services	
–	
Sum of direct costs	0.28 €/m²
Surcharges (20 %)	0.06 €/m²
Unit price	**0.34 €/m²**

2.2.50	**Blunt measure**	15,000.00	m²
	Scattering and rolling-in of spreading grit with a grain size of 1/3. Density 1 kg/m². Removal and recycling of loose material (choice of the contractor).		

Selection of technology:

Spreading grit with a grain size of 1/3 (50 €/t) is scattered und rolled-on in order to enhance skid resistance during the asphalt installation. This is done simultaneously to the application of the asphalt surface using a tandem roller equipped with an attached chip spreader (45 €/h). The scattering and rolling-in of the spreading grit therefore occurs at the same speed as the installation of the asphalt surface (see item 2.1.30): 50 t/h / 2.5 t/m³ / 0.04 m = 500 m²/h.

Calculation:

Labor	
1 x 35 €/h/500 m^2/h	0.07 €/m²
Material	
1,000 kg/m²/1000 kg/t x 50 €/t	0.05 €/m²
Equipment	
45 €/h/500 m²/h	0.09 €/m²
External services	
–	
Sum of direct costs	0.21 €/m²
Surcharges (20 %)	0.04 €/m²
Unit price	**0.25 €/m²**

2.3.4.4 Finishing the bid

After the calculation of the particular items, the bill of quantity now can be provided with the unit prices.

Table 2.11 Bill of quantity with prices

Item	Text	Quantity	Unit	Unit price		Total price
1.	**Preliminary works**					
1.1.	**Excavation works**					
1.1.10.	Mill asphalt and load it up	60.00	m^2	15.47	€/m^2	928.20 €
1.1.20.	Detach asphalt pavement	45.00	m	5.10	€/m	229.50 €
1.2.	**Earthworks**					
1.2.10.	Create subgrade	21,000.00	m^2	0.49	€/m^2	10,290.00 €
1.2.20.	Load and recycle material	600.00	m^3	21.90	€/m^3	13,140.00 €
1.2.30.	Create soil improvement	21,000.00	m^2	4.08	€/m^2	85,680.00 €
2.	**Superstructure**					
2.1.	**Layers without binder material**					
2.1.10.	Create frost protection layer	7,500.00	m^3	29.46	€/m^3	220,950.00 €
2.1.20.	Create road shoulders	4,000.00	m	17.76	€/m	71,040.00 €
2.2.	**Asphalt constructions**					
2.2.10.	Apply asphalt base layer	15,000.00	m^2	17.88	€/m^2	268,200.00 €
2.2.20.	Apply asphalt binder layer	15,000.00	m^2	11.92	€/m^2	178,800.00 €
2.2.30.	Apply asphalt surface	15,000.00	m^2	10.72	€/m^2	160,800.00 €
2.2.40.	Spray on bituminous binder	30,000.00	m^2	0.34	€/m^2	10,200.00 €
2.2.50.	Blunt measure	15,000.00	m^2	0.25	€/m^2	3,750.00 €
Net bid sum						1,024,007.70 €
VAT 19 %						194,561.46 €
Gross bid sum						**1,218,569.16 €**

2.4 Estimating in bridge construction

2.4.1 Basics

2.4.1.1 Construction and solid bridge construction methods

The technical design of a bridge structure focuses on its functional requirements. In addition to the requirements for bearing capacity, they also include other characteristics, such as deformation limits, demands of third parties, and seamless integration into the surrounding environment where the proportions of the construction with respect to its surroundings are of great significance. That means, for example, that tall pillars do not harmonize well with a flat landscape. Moreover, the proportions of the structural shell, including visually obscured parts, play a significant role. The visible surface of abutments and the dimensions of the bridge superstructure should be proportional to one another in order to represent the continuous transition of physical forces into the foundation structures.

The number of bridge spans and their lengths depend on subsoil conditions, landform, and the position of traffic lanes above the bridged terrain. After assessment of the parameters above, the construction method for the bridge superstructure (beam, arch, truss, frame, cable-stayed bridge), and the construction type of the superstructure (reinforced concrete, prestressed concrete, composite steel, or steel) are selected. During this process, the construction height of the superstructure as well as its basic forms and dimensions are determined. During the design process of a bridge structure, great importance is attached to cross-sectional design. The essential construction parameters, which have particular influence on the type of employed support structure, are developed during the design phase.

Single-span slab structures are preferred for bridges that span only short distances because they can be easily manufactured and exhibit a continuous soffit area. The distance is spanned using a solid slab. Hollow, weight-reducing slabs are no longer permitted for bridge structures. For cross-sectional concrete bridge designs, the combined truss and plate design constitutes the ideal type in concrete engineering and consists of main girder, road slab with cantilevers, and optional sublayer topping slab. This type of design is characterized by a continuous cross-sectional area, which is constructed within the range of positive bending compression values over the area of the bridge span where bending compression force applies whereas bending-tensile loads are limited to the width of load-bearing beams, which has a favorable effect on the influences of the structure's dead load. In contrast, negative moments affecting the bridge spans are influenced by the magnitude of beam widths only. Cross-section designs with small widths, therefore, require additional sublayer topping slabs in order to absorb local bending compression loads.

The *box section structure*, an evolution of the combined truss and plate design, consists of a sublayer topping slab, which is a structural requirement in the load-bearing area of the continuous beam. The length of the slab is dependent on the structural zero points in the moment diagram. In order to create a continuous soffit area, the sublayer topping slab is integrated along the total length of the structure.

In addition to the selection of a cross-section, the design of the longitudinal section is also of particular significance in the sector of bridge engineering. The most common designs employed for large bridge constructions are beam, frame, and arch bridges. Truss bridge designs usually find application in steel bridge constructions.

The most striking feature of *beam bridges* is the visual division of the superstructure from the substructure by the level of bearings as the bridge cross-section is assembled and embedded in accordance with the dimensions of the beam. Hence, the actual type of cross-section is irrelevant because the bearings transfer superstructure loads onto the substructure ensuring the required flexibility for the load-bearing beam. Thus, length fluctuations and bending of the superstructure resulting from the influences of shifts in prestress, temperature, and bending forces are absorbed by contorting of the respective bearings.

A *frame construction*, in contrast, is defined by a lack of visible division of superstructure and substructure, and their rigid (i. e. non-bending) connection. The advantage of frame over beam design is that rigid frames relief the loads of the bridge span with respect to moment loading; and, as a result, decreased construction heights are required. Bending loads are transferred to the pillars due to their rigid connection to the superstructure. In return, the pillars exert horizontal thrust at the bearing point.

The *arch bridge* constitutes the classic construction design of reinforced concrete bridges. The main load bearing beam is created by an arch acting as compression member, which exerts significant horizontal thrust at the bearing points. A solid construction ground is required to absorb the horizontal thrust as arches can only be integrated in construction grounds with high rock content. The elevation (i. e. support by pillars) of the traffic lanes results in bending loads in the arch that are super-transferred to the general compression loads. Arch construction designs are most commonly realized in construction projects to span valleys in one go.

2.4.1.2 Characteristics of the pre-estimate

In the field of bridge construction, the following aspects have to be considered when conducting the pre-estimate:

– Project design documents and structural analyses are usually only available after contract acquisition.
– It has to be ensured that the applied construction methods correspond with the client's schedule and have to be realizable in a timely fashion.
– Bridge-construction projects are commonly realized "inch by inch". Due to this rigid and systematic approach, once construction schedules are in place, they can only be modified with some difficulty later on. Moreover, measures to enhance the construction rate are virtually impossible to apply owed to technical limitations. Hence, pre-elimination of potential disruptions to the project is mostly limited.
– The effort that goes into assuring and providing proof of quality (e. g. test reports for steel, performance tests for bridge expansion joints) is comparatively high.
– The high demands on logistics and ensuring traffic safety during project realization require a high level of organization.
– The ability to innovate and company know-how play a significant role in conjunction with creating alternative proposals. The bidding company can gain a decisive competitive edge by showing economical alternatives with respect to the applied construction method and connected cost-savings.
– The possibility to file post-construction claims is strictly limited. Most likely areas for realizable claims are foundation engineering or earthworks.

2.4.2 Example – Steel composite bridge

The example project entails the construction of a steel composite bridge, which is to be constructed in conjunction with a new interchange to the (German) "Bundesautobahn A3". The bridge is going to span the autobahn A3 with a length of 116 m over three bridge spans. An access ramp is required on the west side (in the direction of Frankfurt) that will be connected to the bridge. The level of elevation of the ramp in contrast to the lower A3 traffic lanes requires a boundary in the form of a 150-meter retaining wall, which is part of the bridge construction contract. The autobahn interchange is realized in one direction only. Preliminary to cost calculation and price formation, the pages following detail the construction project, method of construction, and scheduling.

2.4.2.1 Project specifications and construction method

In accordance with the construction performances involved, the bid was divided into the following construction phases:[55)]

- Phase 0: Construction site facilities
- Phase 1: Installation of drainage pipes on the west side
- Phase 2: Bridge structure
- Phase 3: Retaining wall

The bill of quantities issued by the department of transportation includes, among others, the following performances: Preparation of all construction documents required for and by the project, including:

- Structural and ground survey calculations
- Traffic safety measures (single-shift construction sites)
- Removal of the over-wide emergency stopping lane on the west side of autobahn A3
- Construction of new drainage systems along the autobahn in the area between retaining wall and emergency stopping lane (in the direction towards Frankfurt)
- Construction of the bridge structure
- Construction of the retaining wall
- Any other performances listed and detailed in the bill of quantities and other attachments and documents

Bridge construction

Method and scale

The bridge structure entails an arcuate three span bridge with distances between supports of 29.98 m, 47.37 m, and 38.75 m measured at respective joints. The structure is supported along the center line where the second support is positioned next to the road shoulder in the direction of Frankfurt. The geometrical alignment of the pillars in accordance with the horizontal plan follows the axis of the autobahn A3.

Foundation

The west abutment is situated in the slope area next to the autobahn. In order to secure the area during construction, the client has ordered the installation of a sheeting structure. Foundations are constructed at level of the weathered rock ground in order to ensure their uniformity. Concrete is integrated as substitute where necessary. In the section of the pillar, which is situated to the west of the motorway, the stable soil layers, meaning the weathered rock, are located at a depth of 8.20 m. To avoid a deep

55) Construction performances for all phases have to be realized within the total construction time specified in subparagraph 2 of the BVB-Stb (special terms and conditions for road construction).

excavation pit and the associated costly dewatering measures, a pile foundation is provided.

In the area of the pillar situated to the west of the autobahn, load-bearing ground layers, i. e. weathered rock, occur first at a depth of 8.20 m. To avoid the establishment of a deep construction pit and related labor-intensive drainage systems, a pile foundation is constructed instead.

In the area of the pillar situated along the center line and for the east abutment, load-bearing layers of gravel sands begin at a depth of 6.50 m (B 22) and 4.50 m (B 32) below ground level. Since maintenance of water drainage systems during construction of the pile top cap has proved difficult, submerged concrete is integrated after the construction pit has been established. The displaced volumes of water are disposed of by the contractor.

Superstructure

The load-bearing construction of the superstructure consists of a steel composite structure of a single-segment box girder with a construction height of 2 m. “St 52” (carbon steel with a minimum tensile strength of 52 kg/mm²) steel is used for the steel structure and C 35/45 concrete for the reinforced concrete slab. The superstructure is point-mounted onto the abutments in a torsionally rigid manner through placement of two bearings and onto the center pillars through one bearing each. The anchor point of the superstructure is situated in the west abutment set in rock ground at a shallow level. Onto each abutment is mounted a bearing and onto the pillars the single bearing. Both are horizontally rigid. As the superstructure is anchored in the west abutment, a multi-loop expansion joint with an expansion value of about 110 mm is integrated into the east abutment. A single-loop expansion joint absorbs angular displacement forces at the west abutment. Expansion joints have to be integrated and a water drainage of the superstructure is realized through five equally spaced bridge drainage pipes. Their perpendicular drainage pipe can be maintained through two openings in the superstructure installed for the purpose of cleaning. This pipe transitions into a vertical fall pipe before the east abutment and ends in an inspection chamber, which is connected to the road drainage system along the autobahn. Disposal of above-ground water during superstructure construction is performed by the contractor.

Retaining wall

Method and scale

The schedule contains the construction of an angular retaining wall made of reinforced concrete, the foundations for which are terraced according to the sloping elevation of autobahn A3 and divided into 15-meter segments. Following the rising inclination of the foundations, joints are placed at intervals of 7.50 m. A contraction joint is constructed where terraces of foundation segments meet, and a dummy contraction joint is integrated in the center of each segment.

Foundation

The retaining wall is set into natural soil layers at shallow levels. Here, the foundation base of the south wall section connected to the bridge structure from kilometer 0 + 535 to 0 + 610 is set into rock ground close to the surface. Wall heights, in this section, amount to 4 m to about 8 m. Further along, the rock layer submerges deeper into the ground resulting in the foundation base set into aeolian sands and weathering debris respectively. The level of elevation of the foundation base was determined under consideration of the elevation level of autobahn drainage pipes in order to avoid fluvial erosion.

Water drainage

The drainage strip integrated in the backfill area of the erected wall consists of gravel filters and has a thickness of at least 1 m. A filtration pipe at its base provides the required drainage and is connected to the drainage systems of the autobahn.

Preliminary works and simultaneous construction

In the area where the project is to be realized, the client has determined elevation and positioning points, which have to be reviewed by the contractor in order to connect the respective anchoring points for the structures. Trees have been removed beforehand though tree stumps have to be removed by the contractor. Required traffic control and safety measures are implemented at the start of construction by the client. At the autobahn, other construction procedures are realized simultaneously (e. g. retaining wall, road maintenance, etc.). Currently, Structure two is constructed to the east of abutment east. Table 2.12 summarizes technical and construction specifications of the bridge.

Table 2.12 Summary of the construction details and technical data of the steel composite bridge

Construction	Steel composite bridge, trapezoid, single-segment steel box girder bearing untensioned reinforced steel slab consisting of in-situ concrete over three spans
Total length	116.10 m
Widths of individual spans from east to west	29.98 m – 47.37 m – 38.75 m
Bridge height	Gradient of bridge traffic lane positioned between 7.20 m and 7.59 m over top edge of traffic lane A3
Clear height	4.70 m to 4.80 m from bottom edge of steel box girder to top edge of traffic lane A3
Construction height of superstructure	2.50 m
Mass of steel box girder	200 t (St 52)
Mass of superstructure reinforced concrete	1,150 t (C 30/37)

Mass of abutment and support reinforced steel	1,990 t (C 20/25)
Concrete steel	approx. 180 t (BSt 500 S, only steel bars)
Total mass of bridge	approx. 3,500 t
Radius of curvature	190 m
Cross slope	190 m
Foundation	7 %
Expansion value of expansion joint structure on east side	East abutment and pillars: Pile foundation West abutment: Rock ground
Bearing system	Tangential bearing West abutment: 1 rigid bearing, 1 flexible bearing East abutment: 1 partially flexible bearing, 1 flexible bearing West and east pillars: 1 flexible bearing each

Construction process

Abutments and support pillars are manufactured using the in-situ concreting method supported by wooden-girder formwork (Doka FF 20). The horizontal plan shows that the wing walls of the abutments are curved and the inside walls slanted.

The cantilever arms of the superstructure slab are constructed in six segments with the help of a formwork carriage, which entails a steel structure that bears the formwork of the cantilevers and can be moved by a formwork carriage. The formwork of the cantilevers is constructed with rough-cut, tongue-and-groove formwork, which is mounted onto Doka wood girders. The wood girders rest on the steel structure. In order for the formwork carriage to move, the whole formwork carriage construction including formwork facing is lowered. After movement of the formwork carriage, the formwork carriage construction and formwork facing are brought back into position and secured.

Formwork for concrete slabs in the area of the trough are produced using conventional means. Certain technical parameters, such as stripping strength and concrete curing, have to be particularly considered and adjusted in accordance with the construction process.

Moreover, certain safety precautions have to be taken during realization of the construction processes above since they take place over heavy-traffic autobahn lanes.

2.4.2.2 Construction schedule

Creation of the construction schedule entails the division of construction performances involved in the project into tactical work phases; which, in this case, encompass about 200 operative phases that, subsequently, have to be evaluated towards time expenditure and connected accordingly.

Evaluation of time-dependent values has to be performed in conjunction with calculation requisites and the construction deadline provided by the client since the time factor is of pivotal importance for the economic success of the construction site. Extension of the time (as determined in the calculation) required to establish the construction site leads to increased construction costs, though billable reimbursements remain unchanged, and hence degrading construction site results. A potential, contractually agreed, financial penalty certainly negatively impacts results as well. Moreover, it has to be considered that time-related requirements specified in the schedule have to be operationally realizable under present ancillary conditions. If disruptions bring with them the danger of an extension of the total construction time, potential measures to accelerate the construction process have to be investigated in order to mitigate the negative effects of project deadline violations. Considering this example, construction above an autobahn signifies a substantial, to some extent "planned" disruption of the construction schedule. Due to the position of the autobahn, the construction site is divided into two sections, which have to be, at least partially, logistically independent. Hence, numerous partial performances require a comparatively higher time factor for their production and construction.

Connecting operative sections is important in order to swiftly identify consequences that result from changes in the construction schedule or disruptions influencing the construction deadline. To this end, determination of the critical path plays an important role.

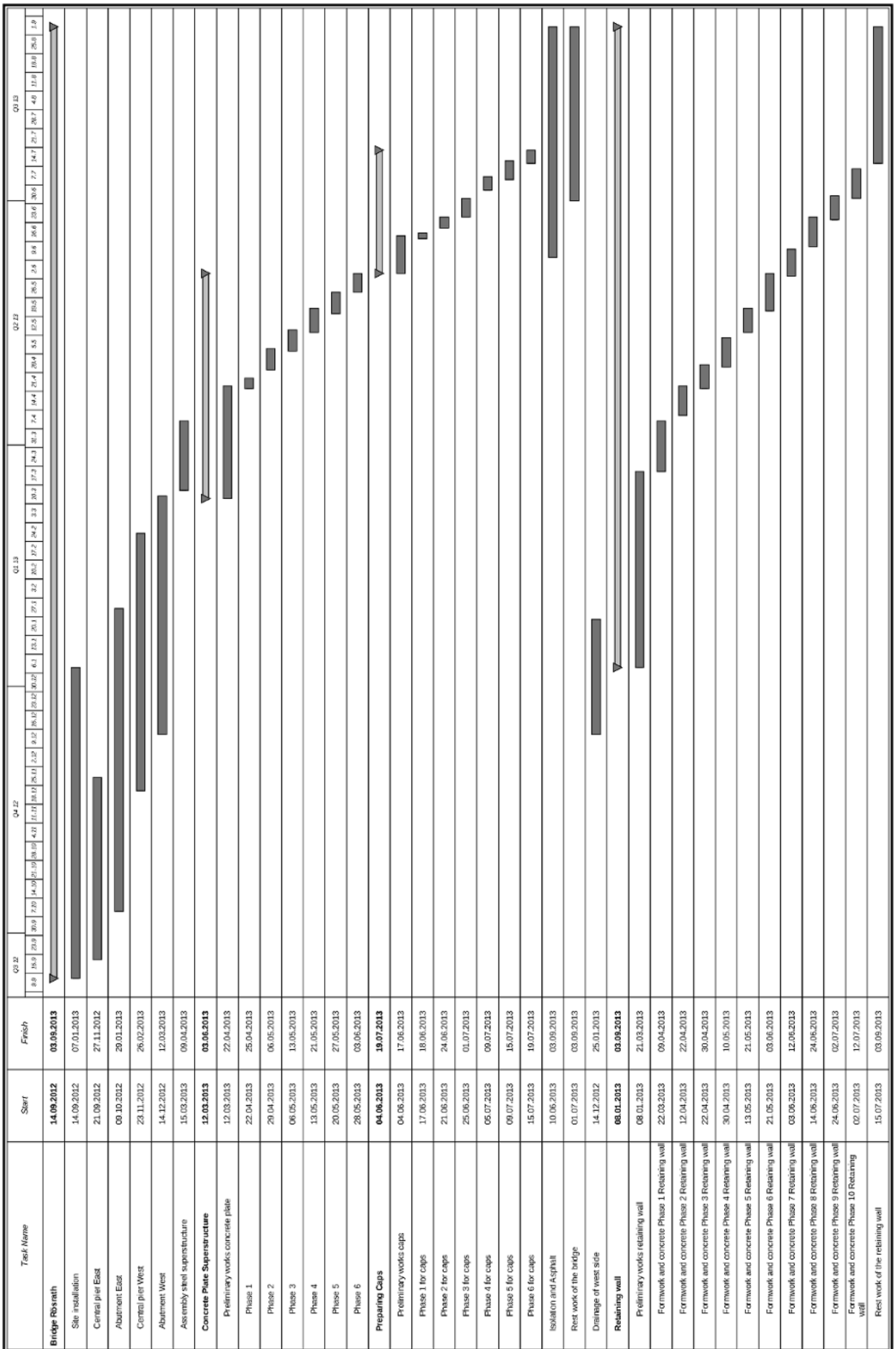

Figure 2.9 Construction schedule of the example steel composite bridge

2.4.2.3 Determination of costs and pricing

The bill of quantities for the project is divided into the following items:

Table 2.13 Bill of quantities items of the steel composite bridge

Item	Description
0.0	Construction site facilities
1.0	Autobahn drainage system
2.0	Preliminary works for bridge
2.1	Construction pits, linings, drainage systems
2.2	Bridge foundation
2.3	Formwork and concreting
2.4	Steel structure
2.5	Drainage of structure
2.6	Sealing and joints
2.7	Bearings and expansion joints
2.8	Miscellaneous items for bridge
2.9	On-demand services for bridge
3.0	Preliminary works for retaining wall
3.1	Construction pits for retaining wall
3.2	Formwork and concreting for retaining wall
3.3	Construction drainage
3.4	Joints for retaining wall
3.5	Miscellaneous items for retaining wall
3.6	On-demand services for retaining wall

Establishment of the construction site is listed as an individual item. The details are shown in Table 2.14. It conveys that the item includes both costs for establishing and clearing the construction site as well as any additional costs that are accrued for individual partial performances in total (overhead costs of partial performances). Establishing costs are determined on the basis of logistical, operative, and tactical considerations, although the most important aid, in this case, is the construction site layout plan, which is not further discussed at this point.

Table 2.14 Bill of quantities of the steel composite bridge

No.	Description	Direct costs in EUR					Production costs in EUR Columns 4 + 5 + 6 + 7	Over-heads in EUR 10 % of column 8	Risk and profit in EUR 3 % of column 8	Total price in EUR columns 8 + 9 + 10
		Labor		Material	Equip-ment	Subcon-tracts				
		h	Costs							
1	2	3	4	5	6	7	8	9	10	11
01	Assy. cont. & trans.	77.00	2,482.48	0.00	0.00	0.00	2,482.48	248.25	74.47	2,805.20
02	Clearing site	50.00	1,612.00	0.00	1,725.13	0.00	3,337.13	333.71	100.11	3,770.95
03	Cont. for trans trucks, etc.		0.00	0.00	7,672.31	0.00	7,672.31	767.23	230.17	8,669.71
04	Water supply	9.00	290.16	0.00	0.00	994.60	1,284.76	128.48	38.54	1,451.78
05	Electricity supply	18.00	580.32	0.00	0.00	994.60	1,574.92	157.49	47.25	1,779.66
06	Bridge for elect. lines		0.00	0.00	0.00	1,989.19	1,989.19	198.92	59.68	2,247.79
07	Water		0.00	0.00	0.00	1,094.06	1,094.06	109.41	32.82	1,236.29
08	Electricity		0.00	0.00	0.00	1,094.06	1,094.06	109.41	32.82	1,236.29
09	Telecommu-nication		0.00	0.00	0.00	1,094.06	1,094.06	109.41	32.82	1,236.29
10	Heating		0.00	0.00	0.00	820.54	820.54	82.05	24.62	927.21
11	Duo-con-tainers rent		0.00	0.00	956.99	0.00	956.99	95.70	28.71	1,081.40
12	Foreman's office rent		0.00	0.00	956.99	0.00	956.99	95.70	28.71	1,081.40
13	Sanitary facilities rent		0.00	0.00	1,522.78	0.00	1,522.78	152.28	45.68	1,720.74
14	Crew con-tainers rent		0.00	0.00	1,640.64	0.00	1,640.64	164.06	49.22	1,853.92
15	Material containers rent		0.00	0.00	955.20	0.00	955.20	95.52	28.66	1,079.38
16	Scaffolding		0.00	0.00	0.00	22,378.40	22,378.40	2,237.84	671.35	25,287.59
17	Traffic safety scaf-folding		0.00	0.00	0.00	8,951.36	8,951.36	895.14	268.54	10,115.04
18	Rent for crane & trans. costs		0.00	0.00	0.00	30,608.68	30,608.68	3,060.87	918.26	34,587.81
19	Assy. & disass of crane		0.00	0.00	0.00	4,972.98	4,972.98	497.30	149.19	5,619.47
20	Crane elect. costs		0.00	27,848.68	0.00	0.00	27,848.68	2,784.87	835.46	31,469.01

No.	Description	Direct costs in EUR					Production costs in EUR Columns 4 + 5 + 6 + 7	Over-heads in EUR 10 % of column 8	Risk and profit in EUR 3 % of column 8	Total price in EUR columns 8 + 9 + 10
		Labor		Material	Equip-ment	Subcon-tracts				
		h	Costs							
1	2	3	4	5	6	7	8	9	10	11
21	Crane operator	2,873.00	92,625.52	0.00	0.00	0.00	92,625.52	9,262.55	2,778.77	104,666.84
22	Elect. distribution & box		0.00	0.00	954.81	954.81	1,909.62	190.96	57.29	2,157.87
23	Survey		0.00	0.00	0.00	14,918.93	14,918.93	1,491.89	447.57	16,858.39
24	Creation main site road		0.00	0.00	0.00	14,918.93	14,918.93	1,491.89	447.57	16,858.39
25	Removal main site road		0.00	0.00	0.00	4,972.98	4,972.98	497.30	149.19	5,619.47
26	Site estab-lishment by Lavis		0.00	0.00	0.00	24,983.61	24,983.61	2,498.36	749.51	28,231.48
27	Structural analysis by Lavis (superstruc-ture)		0.00	0.00	0.00	14,252.12	14,252.12	1,425.21	427.56	16,104.89
28	Structural analysis by Uhlenberg		0.00	0.00	0.00	44,756.80	44,756.80	4,475.68	1,342.70	50,575.18
29	Excavation work for piles		0.00	0.00	0.00	7,459.47	7,459.47	745.95	223.78	8,429.20
30	Crane for retaining wall		0.00	0.00	0.00	7,459.47	7,459.47	745.95	223.78	8,429.20
31	Excavator (lifting equipment)		0.00	0.00	0.00	5,221.63	5,221.63	522.16	156.65	5,900.44
32	VW bus		0.00	0.00	4,475.68	0.00	4,475.68	447.57	134.27	5,057.52
33	Outside toilet		0.00	0.00	0.00	765.84	765.84	76.58	22.98	865.40
34	Concrete controlling		0.00	0.00	0.00	8,454.06	8,454.06	845.41	253.62	9,553.09
35	Foreman		65,643.31	0.00	0.00	0.00	65,643.31	6,564.33	1,969.30	74,176.94
36	Site manager		49,232.48	0.00	0.00	0.00	49,232.48	4,923.25	1,476.97	55,632.70
37	Frequency converter		0.00	0.00	597.75	0.00	597.75	59.78	17.93	675.46
38	Industrial vibrators		0.00	0.00	1,701.26	0.00	1,701.26	170.13	51.04	1,922.43

No.	Description	Direct costs in EUR					Production costs in EUR Columns 4 + 5 + 6 + 7	Over-heads in EUR 10 % of column 8	Risk and profit in EUR 3 % of column 8	Total price in EUR columns 8 + 9 + 10
		Labor		Material	Equip-ment	Subcon-tracts				
		h	Costs							
1	2	3	4	5	6	7	8	9	10	11
39	Automatic level “NI 2”		0.00	0.00	574.38	0.00	574.38	57.44	17.23	649.05
40	Submersible pump		0.00	0.00	530.62	0.00	530.62	53.06	15.92	599.60
41	Angle grinder		0.00	0.00	590.79	0.00	590.79	59.08	17.72	667.59
42	Circular hand saw		0.00	0.00	164.11	0.00	164.11	16.41	4.92	185.44
43	Power drill		0.00	0.00	142.23	0.00	142.23	14.22	4.27	160.72
44	Power cables		0.00	0.00	547.03	0.00	547.03	54.70	16.41	618.14
45	Circular saw bench		0.00	0.00	355.57	0.00	355.57	35.56	10.67	401.80
46	Concrete bucket		0.00	0.00	415.74	0.00	415.74	41.57	12.47	469.78
47	Rammer		0.00	0.00	455.52	0.00	455.52	45.55	13.67	514.74
48	Gas torch		0.00	0.00	765.84	0.00	765.84	76.58	22.98	865.40
49	Storage boxes		0.00	0.00	330.21	0.00	330.21	33.02	9.91	373.14
50	Bearing blocks		0.00	0.00	105.43	0.00	105.43	10.54	3.16	119.13
51	Tools & small equip-ment		0.00	0.00	1,874.81	0.00	1,874.81	187.48	56.24	2,118.53
52	Trans. costs for mgmt. personnel		0.00	0.00	3,938.60	0.00	3,938.60	393.86	118.16	4,450.62
53	Mats. for establishing site		0.00	2,486.49	0.00	0.00	2,486.49	248.65	74.59	2,809.73
54	Anchors		0.00	0.00	0.00	9,945.96	9,945.96	994.60	298.38	11,238.94
55	Formwork carriage support structure		0.00	0.00	0.00	19,891.91	19,891.91	1,989.19	596.76	22,477.86
	Sum	3,027.00	212,466.27	30,335.17	33,950.42	253,949.05	530,700.91	53,070.10	15,921.02	599,692.03

Costs related to the establishment of the construction site are divided into time fixed and time variable provision costs. To the category of fixed costs belong assembly, disassembly, and transport costs; office and material containers, and construction site cranes; installation costs of construction site supply lines and waste management facilities including main site road; storage yard, scaffolding, and traffic safety and control management for the construction site; costs for structural engineering; survey costs;

costs for concrete controlling, etc. Variable establishing costs include commodities such as electricity, water, telecommunication, rents for containers and equipment, operating costs for lifting equipment, provision and maintenance costs for scaffolding, traffic safety management during site establishment, main construction road, etc. The variable costs were determined under consideration of a certain construction time; which, in this case, is eleven months. Commonly, time variable costs amount to 40 to 60 % of total site facility costs.

In this specific case, foreman and site management costs were determined through cost calculations for the establishment of the construction site and hence are not included in the calculations for average wage. The site establishment cost structure is of particular importance when working with public clients. The contractor is obligated to lodge their initial calculation in case post-construction claims arise. If the construction time is extended as the result of post-construction performances, costs for management and foreman remain fully billable even if relevant claims are settled by subcontractors. Furthermore, site establishment or overhead costs are not lost if the performance amount turns out to be less than the bid value.

In the following example, the pre-estimate is demonstrated using a section of the bill of quantities (Item 2.1 – Construction pits, linings, drainage.)

Table 2.15 Title 2.1 Bill of quantities of the steel composite bridge

Item	Description	Quantity	Unit	Unit price (EUR/Unit)	Total price (EUR)
	Item 2.1: Construction pits, linings, drainage				
2.101	Install pit linings in accordance with structural and construction requirements. Construction pit for west abutment (pit safety measures). Depth over 2.0 m to 4.0 m. Type of pit lining: Girder infilled with timber planks installed through boring. Otherwise, leave pit linings as is.	25.00	m^2		
2.102	Install pit linings. Construction pit depth amounts to 4.0 to 6.0 m. See above for other parameters.	40.00	m^2		
2.103	Install pit linings in accordance with structural and construction requirements. The construction pit for supports and pillars is 1.25 to 3 m deep. Type of pit lining: Steel pile wall integrated through pile driving method.	70.00	m^2		

Item	Description	Quantity	Unit	Unit price (EUR/ Unit)	Total price (EUR)
2.104	Reduce pit linings. Reduce pit linings in accordance with client demands. Type of pit lining: Steel pile wall. Contractor can choose method. New top level height = 50 cm below top level of terrain. Removed materials are property of contractor, who is responsible for their removal.	26.00	m		
2.105	Install pit linings in accordance with structural and construction requirements. The construction pit for supports and pillars is 1.25 to 3 m deep. Type of pit lining: Steel pile wall integrated through pile driving method. Otherwise, leave pit linings as is.	30.00	m^2		
2.106	Reduce pit linings. Reduce pit linings in accordance with client demands. Type of pit lining: Steel pile wall. Contractor can choose method. New top level height = 50 cm below top level of terrain. Removed materials are property of contractor, who is responsible for their removal.	13.50	m		
2.107	Establish construction pit. Excavate ground of present soil classes 3 to 5 for pit. Create pit for abutments and abutment walls. Pit depth is up to 1.25 m. Excavated soils are property of contractor, who is responsible for their removal.	65.00	m^3		
2.108	Establish construction pit. Excavate ground of present soil classes 3 to 5 for western abutment. Depth of pit based on graph and respective ground surveys. Clear present drainage pipes and chambers. Removal of drainage pipes and chambers is billed separately. Excavated materials are property of contractor, who is responsible for their removal. The performance is billed according to excavated profiles.	650.00	m^3		

Item	Description	Quantity	Unit	Unit price (EUR/Unit)	Total price (EUR)
2.109	Excavate rock (additional performance). Excavate rock of class 6. Location = construction pit for west abutment. Billed are additional efforts required due to harder excavation and utilization.	250.00	m^3		
2.110	Excavate rock (additional performance). Excavate difficult rock of class 7 in construction pit. Billed are additional efforts required due to harder excavation and utilization.	100.00	m^3		
2.111	Establish construction pit. Excavate ground of present soil classes 3 to 5 for supports and pillars. Pit depth is over 1.75 to 3 m. Excavated soils are property of contractor, who is responsible for their removal.	270.00	m^3		
2.112	Employ and operate drainage pump. Assemble and maintain operable pump to drain and keep clear construction pit. Disassemble after operation. Geodetic head measured from construction pit floor is 7.5 m at maximum. Performances required for sumps, supply and delivery pipes, and relocation are not billed separately. Required operating hours are billed. The offered standard price applies regardless of the amount of billed hours. Flow rates above 4 to 8 m amount to m3/h. Location: West abutment.	350.00	h		
2.113	Assemble and operate pump. See above. Location: West support.	300.00	h		
2.114	Assemble and operate pump. See above. Location: East abutment.	150.00	h		
2.115	Drain water from construction pit. Drain and dispose water from construction pit. Location = construction pit for center pillar. Dispose water displaced after integration of submerged concrete, which becomes property of the contractor, who is responsible for its disposal.	30.00	m^3		

Item	Description	Quantity	Unit	Unit price (EUR/Unit)	Total price (EUR)
2.116	Transport soil and integrate it into construction pit. Transport, integrate, and compact soil for filling of construction pit. Materials: Gravel-sand mix. Location: Construction pit for supports and pillars.	120.00	m^3		
2.117	Transport soil and integrate it into construction pit. See above. Location: Construction pit for abutments and abutment walls.	20.00	m^3		
2.118	Transport soil and integrate it into construction pit. See above. Location: Construction pit for abutments and abutment walls.	100.00	m^3		
2.119	Transport soil and integrate it into construction pit. See above. Location: Construction pit for abutments.	25.00	m^3		
	Item 2.1 total				

First, individual costs for partial services are determined for the respective items. Individual costs include costs for contractor and subcontractor services. Subcontractor services for the example structure herein amount to approx. 50 % of the total construction volume and are hence a pivotal factor.

Individual costs, which entail wage, material, and equipment costs, for partial services (individual items) rendered by the contractor are determined based on required working hours, materials, and equipment employed per service item.

Wage costs include union wages, premiums, bonuses, social costs, ancillary wage costs, and other benefits. The calculation for the average wage value for the project is shown in the following. As mentioned above, management and foreman costs have been considered during cost determinations for construction site establishment and overheads of partial services respectively.

No.	Occupational group	Individual pay (EUR/h)	Crew pay (EUR/h)
1	Foremen	16.27	16.27
4	Specialist engineer	15.48	61.92
2	Machine operator	14.18	28.36
7			**106.55**

Base average wage	106.55 €/h/7 workers	15.22 €/h
Overtime premium		
1st overtime hour	15.22 €/h x 0.25/9 h	0.42 €/h
2nd overtime hour	15.22 €/h x 0.50/10 h	0.76 €/h
= Subtotal		16.40 €/h
Social costs (S) (86 % of 16.40 €/h)	16.40 €/h x 0.86	14.10 €/h
= Subtotal		30.50 €/h
Employee on-costs		1.74 €/h
= average wage		**32.24 €/h**

The average wage value of a partial service is the result of multiplying the average wage by the expenditure value of the partial service, the standard values of which are either based on experience values gained from post-calculations of similar projects or on specialized literature. It should be noted that the latter represents reference points which have to be adjusted for present conditions.

As far as material costs are concerned, quantity components are either listed in the bid or can be determined through a quantity calculation. Company-internal material purchase price lists can be consulted for the required prices provided they are up to date since otherwise material price offers have to be invited, evaluated, and afterwards included in the pre-estimate. Though, auxiliary materials and small equipment - such as formwork, spacers, and formwork clamps - are commonly included using experience values.

Equipment costs consist of operating and retaining costs, whereas the determination of costs for contractor equipment usually entails retaining costs only, which include depreciation, interest, and maintenance. Here, the register of construction equipment is the basis for the calculation. However, it has to be noted that values listed in the register for monthly depreciation and interest rates as well as monthly maintenance costs are averages that are subject to certain additions or subtractions in accordance with company experience values and unique conditions of the present construction site. Equipment that is required for the project but not part of the company inventory necessitates an inquiry on the free market (purchase, leasing, or rent). Equipment costs that cannot be allocated to described work requirements of a partial service are determined as part of the costs for site establishment.

Costs for third-party services are accrued if parts of the contractual construction service are rendered by third-party companies (subcontractors) instead of the contractor. Which parts of the bill of quantities exactly pertain to subcontractor services depends on the structure and business sector of the invited construction company. In the example used herein, subcontractor services amount to ca. 50 % of the total construction service. Hence, subcontracted services have a significant impact on the project result. Thus, when determining costs, it is important to uphold a high level of scrupulousness. In particular, prices of subcontracted services have to be on hand as firm offers, which are usually renegotiated after contract acquisition, during the calculation of the bid price. In the example, the steel construction company is the most important subcontractor occupying half of the subcontracted services and hence a cost volume of about 25 % of the total construction project.

Table 2.16 shows individual cost elements for item 2.1 "Construction pits, pit lining, drainage."

Table 2.16 Individual costs per quantity unit of item 2.1 of the steel composite bridge

Item	Short description	Qty.	Unit	Labor		Materials	Equipment	Subcontr.	Total
				h/QU	EUR/QU	EUR/QU	EUR/QU	EUR/QU	EUR/QU
2.101	Construction of pit linings	25.00	m^2	1.50	48.36	69.62	44.76	14.17	176.91
2.102	Construction of pit linings	40.00	m^2	1.50	48.36	69.62	59.68	14.17	191.83
2.103	Construction of pit linings	70.00	m^2	1.50	48.36	94.49	9.95	14.17	166.97
2.104	Reduction of pit linings	26.00	m		0.00	0.00	0.00	39.78	39.78
2.105	Construction of pit linings	30.00	m^2	1.50	48.36	94.49	9.95	14.17	166.97
2.106	Reduction of pit linings	13.50	m		0.00	0.00	0.00	39.78	39.78
2.107	Establishment of construction pit	65.00	m^3		0.00	0.00	0.00	13.29	13.29
2.108	Establishment of construction pit	650.00	m^3		0.00	0.00	0.00	13.29	13.29
2.109	Excavation of rock (additional service)	250.00	m^3		0.00	0.00	0.00	3.58	3.58
2.110	Excavation of rock (additional service)	100.00	m^3		0.00	0.00	0.00	31.53	31.53
2.111	Establishment of construction pit	270.00	m^3		0.00	0.00	0.00	13.29	13.29
2.112	Assembly and operating of pump	350.00	h	0.05	1.61	1.47	1.49	0.00	4.57
2.113	Assembly and operating of pump	300.00	h	0.05	1.61	1.47	1.49	0.00	4.57

2.114	Assembly and operating of pump	150.00	h	0.05	1.61	1.47	1.49	0.00	4.57
2.115	Draining of water from construction pit	30.00	m^3	0.10	3.22	1.72	2.98	0.00	7.92
2.116	Transport and integration of gravel-sand mix	120.00	m^3		0.00	0.00	0.00	19.70	19.70
2.117	Transport and integration of gravel-sand mix	20.00	m^3		0.00	0.00	0.00	19.70	19.70
2.118	Transport and integration of gravel-sand mix	100.00	m^3		0.00	0.00	0.00	19.70	19.70
2.119	Transport and integration of gravel-sand mix	25.00	m^3		0.00	0.00	0.00	19.70	19.70

Production costs of respective items are the result of multiplying individual costs by their quantity. Individual costs for respective items do not have to include additional charges for overheads since the item for construction site facilities already includes overheads. As a result, production costs and individual costs are identical. The example assumes a 10 % charge on production costs to account for overhead costs of the construction site. The risk-reward value amounts to 3 % of the production costs for the project. Contained in this additional charge are tactical and market-political deliberations in conjunction with present market conditions and activity as well as the specialized structure and current business situation of the company in question. The total price is determined by adding the production costs of respective partial services and a percentage general overhead cost value plus percentage risk-reward value. Table 2.17 shows the respective calculations.

Table 2.17 All-in prices of the title 2.1 of the steel composite bridge

Item	Qty.	Unit	Cost elements total EUR/Unit	Production costs EUR	General overheads EUR	Risk and profit EUR	Total price EUR
2.101	25.00	m^2	176.91	4,422.75	442.30	132.68	4,997.73
2.102	40.00	m^2	191.83	7,673.20	767.32	230.20	8,670.72
2.103	70.00	m^2	166.97	11,687.90	1,168.79	350.64	13,207.33
2.104	26.00	m	39.78	1,034.28	103.43	31.03	1,168.74
2.105	30.00	m^2	166.97	5,009.10	500.91	150.27	5,660.28
2.106	13.50	m	39.78	537.03	53.70	16.11	606.84
2.107	65.00	m^3	13.29	863.85	86.39	25.92	976.16

Item	Qty.	Unit	Cost elements total EUR/Unit	Production costs EUR	General overheads EUR	Risk and profit EUR	Total price EUR
2.108	650.00	m^3	13.29	8,638.50	863.85	259.16	9,761.51
2.109	250.00	m^3	3.58	895.00	89.50	26.85	1,011.35
2.110	100.00	m^3	31.53	3,153.00	315.30	94.59	3,562.89
2.111	270.00	m^3	13.29	3,588.30	358.83	107.65	4,054.78
2.112	350.00	h	4.57	1,599.50	159.95	47.99	1,807.44
2.113	300.00	h	4.57	1,371.00	137.10	41.13	1,549.23
2.114	150.00	h	4.57	685.50	68.55	20.57	774.62
2.115	30.00	m^3	7.92	237.60	23.76	7.13	268.49
2.116	120.00	m^3	19.70	2,364.00	236.40	70.92	2,671.32
2.117	20.00	m^3	19.70	394.00	39.40	11.82	445.22
2.118	100.00	m^3	19.70	1,970.00	197.00	59.10	2,226.10
2.119	25.00	m^3	19.70	492.50	49.25	14.78	556.53
Sum					5,661.73	1,698.54	63,977.28

The completed bill of quantities is shown below.

Table 2.18 Complete bill of quantities for item 2.1 of the steel composite bridge

Item	Description	Quantity	Unit	Unit price (EUR/QU)	Total price (EUR)
	Item 2.1: Construction pits, linings, drainage				
2.101	Installation of pit linings in accordance with structural and construction requirements. Construction pit for west abutment (pit safety measures). Depth over 2.0 m to 4.0 m. Type of pit lining: Girder infilled with timber planks installed through boring. Otherwise, leave pit linings as is.	25.00	m^2	199.91	4,997.73
2.102	Installation of pit linings. Construction pit depth amounts to 4.0 to 6.0 m. See above for other parameters.	40.00	m^2	216.77	8,670.72

Item	Description	Quantity	Unit	Unit price (EUR/QU)	Total price (EUR)
2.103	Installation of pit linings in accordance with structural and construction requirements. The construction pit for supports and pillars is 1.25 to 3 m deep. Type of pit lining: Steel pile wall integrated through pile driving method. Otherwise, leave pit linings as is.	70.00	m^2	188.68	13,207.33
2.104	Reduction of pit linings. Reduce pit linings in accordance with client demands. Type of pit lining: Steel pile wall. Contractor can choose realization method. New top level height is 50 cm below top level of terrain. Removed materials are property of contractor, who is responsible for their removal.	26.00	m	44.95	1,168.74
2.105	Installation of pit linings in accordance with structural and construction requirements. The construction pit for supports and pillars is 1.25 to 3 m deep. Type of pit lining: Steel pile wall integrated through pile driving method. Otherwise, leave pit linings as is.	30.00	m^2	188.68	5,660.28
2.106	Reduction of pit linings. Reduce pit linings in accordance with client demands. Type of pit lining: Steel pile wall. Contractor can choose realization method. New top level height is 50 cm below top level of terrain. Removed materials are property of contractor, who is responsible for their removal.	13.50	m	44.95	606.84
2.107	Establishment of construction pit. Excavate ground of present soil classes 3 to 5 for pit. Create pit for abutments and abutment walls. Pit depth is up to 1.25 m. Excavated soils are property of contractor, who is responsible for their removal.	65.00	m^3	15.02	976.16

Item	Description	Quantity	Unit	Unit price (EUR/QU)	Total price (EUR)
2.108	Establishment of construction pit. Excavate ground of present soil classes 3 to 5 for western abutment. Depth of pit based on graph and respective ground surveys. Clear present drainage pipes and chambers. Removal of drainage pipes and chambers is billed separately. Excavated materials are property of contractor, who is responsible for their removal. The service is billed according to excavated profiles.	650.00	m^3	15.02	9,761.51
2.109	Excavation of rock (additional service). Excavate rock of class 6. Location = construction pit for west abutment. Billed are additional efforts required due to harder excavation and utilization.	250.00	m^3	4.05	1,011.35
2.110	Excavation of rock (additional service). Excavate difficult rock of class 7 in construction pit. Billed are additional efforts required due to harder excavation and utilization.	100.00	m^3	35.63	3,562.89
2.111	Establishment of construction pit. Excavate ground of present soil classes 3 to 5 for supports and pillars. Pit depth is over 1.75 to 3 m. Excavated soils are property of contractor, who is responsible for their removal.	270.00	m^3	15.02	4,054.78
2.112	Employment and operating of drainage pump. Assemble and maintain operable pump to drain and keep clear construction pit. Disassemble after operation. Geodetic head measured from construction pit floor is 7.5 m at maximum. Services required for sumps, supply and delivery pipes, and relocation are not billed separately. Required operating hours are billed.	350.00	h	5.16	1,807.44

Item	Description	Quan-tity	Unit	Unit price (EUR/QU)	Total price (EUR)
	The offered standard price applies regardless of the amount of billed hours. Flow rates above 4 to 8 m amount to m^3/h. Location: West abutment.				
2.113	Assembly and operating of pump. See above. Location: West support.	300.00	h	5.16	1,549.23
2.114	Assembly and operating of pump. See above. Location: East abutment.	150.00	h	5.16	774.62
2.115	Draining of water from construction pit. Drain and dispose of water from construction pit. Location = construction pit for center pillar. Dispose of water displaced after integration of submerged concrete, which becomes property of the contractor, who is responsible for its disposal.	30.00	m^3	8.95	268.49
2.116	Transport and integration of soil into construction pit. Transport, integrate, and compact soil for filling of construction pit. Materials: Gravel-sand mix. Location: Construction pit for supports and pillars.	120.00	m^3	22.26	2,671.32
2.117	Transport and integration of soil into construction pit. See above. Location: Construction pit for abutments and abutment walls.	20.00	m^3	22.26	445.22
2.118	Transport and integration of soil into construction pit. See above. Location: Construction pit for abutments and abutment walls.	100.00	m^3	22.26	2,226.10
2.119	Transport and integration of soil into construction pit. See above. Location: Construction pit for abutments.	25. 00	m^3	22.26	556.53
	Item 2.1 total				**63,977.28**

After determining costs and prices for the remaining items similar to the above, the bid sum is determined and compiled. In the example, cumulative wage hours amount to 10,764.16 h.

Table 2.19 Compilation of all titles of the steel composite bridge

Item	Description	Net bid price in EUR	VAT. (19 %) in EUR	Gross bid price in EUR
0.0	Construction site facilities	599,692.03	113,941.49	713,633.52
1.0	Autobahn drainage system	109,853.51	20,872.17	130,725.68
2.0	Preliminary works for bridge	10,438.89	1,983.39	12,422.28
2.1	Construction pits, linings, drainage systems	63,977.28	12,155.68	76,132.96
2.2	Bridge foundation	134,353.60	25,527.18	159,880.78
2.3	Formwork and concreting	548,803.67	104,272.70	653,076.37
2.4	Steel structure	462,787.43	87,929.61	550,717.04
2.5	Drainage of construction	39,407.07	7,487.34	46,894.41
2.6	Sealing and joints	69,993.94	13,298.85	83,292.79
2.7	Bearings and expansion joints	90,569.19	17,208.15	107,777.34
2.8	Miscellaneous items for bridge	24,732.61	4,699.20	29,431.81
2.9	On-demand services for bridge	18,777.16	3,567.66	22,344.82
3.0	Preliminary works for retaining wall	21,846.33	4,150.80	25,997.13
3.1	Construction pits for retaining wall	85,411.40	16,228.17	101,639.57
3.2	Formwork and concreting for retaining wall	230,099.80	43,718.96	273,818.76
3.3	Drainage of construction	3,808.22	723.56	4,531.78
3.4	Joints for retaining wall	13,104.31	2,489.82	15,594.13
3.5	Miscellaneous items for retaining wall	31,398.84	5,965.78	37,364.62
3.6	On-demand services for retaining wall	16,354.15	3,107.29	19,461.44
	Total	**2,575,409.43**	**489,327.80**	**3,064,737.23**

2.4.3 Example – Prestressed concrete bridge

2.4.3.1 Project specifications

The following example entails a three-span prestressed concrete bridge. The superstructure consists of two double-webbed slab girders, both resting on box abutments with foundations integrated into the terrain to a shallow depth, and central pillar supports. The project also entails technical processing of construction documents, local required pre-construction, ground, and post-construction work including construction roads for delivery, and transportation, and subsequent as-built documentation. A standard cross-section for German autobahn bridges – RQ 29,5 – is employed.[56)] The route of the traffic lane in the immediate area of the structure is marked in a straight line. The autobahn centerline is crossed by a brook below (almost) perpendicularly. The gradient of the traffic lane in the immediate area of the structure follows a depressed course. Effectively, this means an average longitudinal inclination for the bridge of about 0.035 % (0.063 % [southern abutment] ... 0.011 % [northern abutment]). The cross slope value for both superstructures continuously amounts to 2.5 % towards the structure's east side.

Table 2.20 Summary of technical and construction data of the prestressed concrete bridge

Structural system/construction type of superstructure	Three-span beam and slab bridge with two double-webbed prestressed concrete superstructures supported by box abutments und center pillars with shallow foundations
Construction height of superstructure	0.85 – 1.50 – 1.00 m/0.925 – 1.575 – 1.075 m
Abutment cross-section	Shear wall (dia = 1.50 m), external visible concrete surface
Pillar cross-section	Shear wall (dia = 1.00 m), external visible concrete surface
Foundation	Shallow foundation (dia = 1.20 m)
External influences	acc. DIN technical papers 101—cf. subparagraph 3.10 and construction plans
Traffic system	acc. DIN technical papers 102—large distance
Individual support widths	15.00 m/21.00 m/15.00 m
Total length between end bearings	51.00 m
Clear distance between abutments	50.00 m
Lowest clear height	1.22 m above terrain
Intersection angle	100.00 gon
Width between guardrails	≥ 29.92 m (inner parapet edges)
Bridge surface area	2 x 742.56 m² (Σ = 1,485.12 m²)

56) In accordance with RAS-Q (German Standard for Road Construction - Part: Cross-sections).

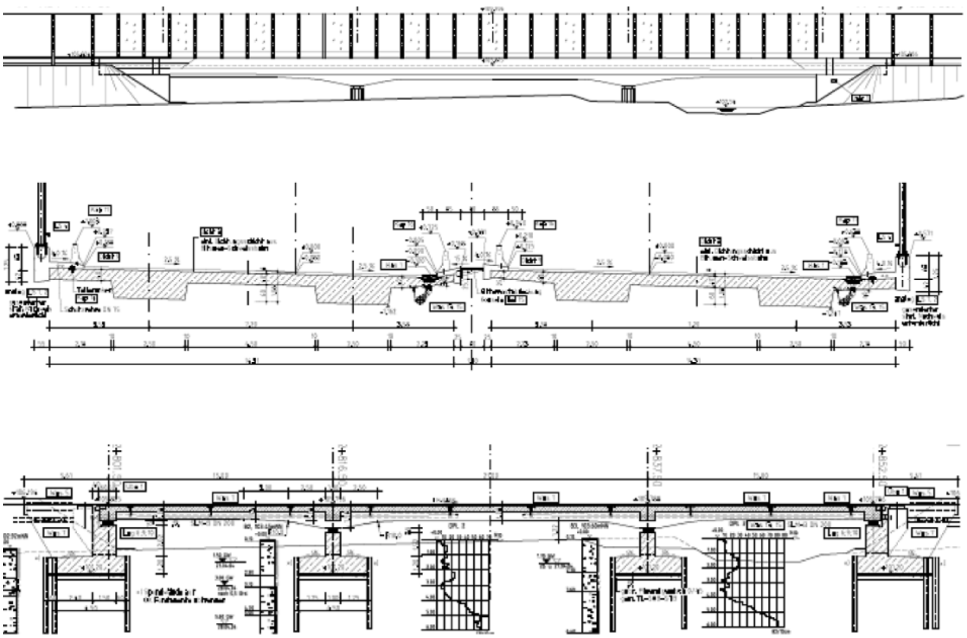

Figure 2.10 Design schemes of the prestressed concrete bridge

The structural design of bridge constructions is usually made by the client, whereas the realization schedule is created by the contractor. Scrupulous review and evaluation of provided documents for a submission of bids are indispensable for a successful calculation:

– Bid conditions
– Special contract conditions
– Service description
– Construction specifications
– Bill of quantities
– Additional technical contract conditions
– Basic engineering design
– Construction site survey
– Etc.

The hierarchy of individual elements contained in bid documents is of particular importance in case of potential discrepancies; however, in any case, identified discrepancies have to be cleared up before beginning with the calculations. Furthermore, an inspection of the premises is advisable. Project management personnel, estimator, and, if required, the work preparation department and engineering offices should already have become a closely-knit operation during this phase.

Table 2.21 Bill of quantities of the prestressed concrete bridge

Item	Description	Qty.	QU	Unit price (EUR/QU)	Total price (EUR)
	Bridge construction				
1	**Construction site facilities**				
1.1	**Establishment and provisioning of construction site facilities** Transport and provision equipment, tools, and other operating resources required for the contractual realization of construction services to construction site, and assemble and make equipment ready for construction provided the employment of equipment is not billed separately. Create facilities including construction offices, accommodations, workshops, storage units and so on; and, if required, transport, assemble, and install related units and elements. Install electricity, water, telecommunication lines, and sanitary facilities to required extent. If needed, create storage space, delivery roads, and other infrastructure. Perform topsoil work, as required, including removal of local plant growth. Moreover, create surface areas for construction work if those provided by the client do not suffice. Provision, maintenance, and operating costs of equipment, facilities, and installations including rents, fees, and so forth are not billed using standard rates but rather using the unit price of the respective partial service. Provided that separate items for services involving the establishment of the construction site are not included in the bill of quantities, the standard rate applies to all services across all sections in the bill of quantities. Create vehicle access road to the construction site, which is billed separately.	1	ea		

1.2	**Clearing of construction site** Clear all equipment, facilities, installations, and so forth from construction site. Restore used surface areas and roads according to their initial state. If the bill of quantities does not list separate items for the clearing of the construction site, the standard rate applies to all services across all sections of the bill of quantities.	1	ea		
	Construction site facilities total				
2	**Bridge structure**				
2.1	**Production of reinforced concrete including formwork** Produce reinforced concrete and formwork according to documents provided by the client. Provision and remove formwork. Reinforcing and scaffolding are not billed separately. Components = abutment + abutment walls, substructure inspection chamber. Utilized material = reinforced concrete. Compressive strength class C30/37. Exposure classes XF2, XC4, and XD1. Additional requirements: w/c ratio ≤ 0.5. Visible surface area of formwork = timber boards planed on one side of identical cross-section with profiled sides (tongue and groove or similar). Formwork is assembled horizontally. Deburr surface area mechanically.	255.00	m^3		
2.2	**Transport and integration of reinforced concrete** Integrate reinforced concrete in accordance with structural and construction requirements. Components = foundation, abutment with abutment wall, central pillar, bearing pedestal, chamber wall, revision chamber. Type of steel = BSt 500 S.	85.00	t		
	Bridge structure total				
	Bridge construction total				

2.4.3.2 Construction schedule

Prior to processing calculations using calculation software, comprehensive technical preparation of the project and scrupulous analysis of all involved processes are required. To this end, a construction schedule has to be created. Furthermore, the establishment of the construction site has to be planned, and auxiliary structures have to be constructed accordingly; subcontractor and supplier lists need to be compiled, and the average wage value has to be determined. In order to identify potential ambiguities between individual parts of the contract, it is advisable to estimate quantities listed in contractual documents and compare them to the quantities listed in the bill of quantities.

A bar chart is suitable to demonstrate the construction schedule of a bridge structure, which is usually realized with a centralized construction site. The program "Power Projekt", for example, can visualize scheduled processes and interdependencies between individual operative phases via bars and links.

All professional groups involved are arranged into essential operative phases and considered in conjunction with their operative time requirements. A detailed construction schedule ensures identification and visualization of optimizable areas - which have an impact on prices - of the "critical path" and later, of potential disruptions on schedule and deadline. It should be noted that allocation to and duration of time elements in the operative phases (bars) have to match actual calculated values later. If necessary, the construction schedule has to be adjusted during the calculation phase. In any case, construction and intermediate deadlines provided by the client have to be observed.

An uninterrupted schedule, based on the calculated, optimized sequence of construction phases, is of significant importance to economic success. The reallocation of construction time (e. g. to a more unfavorable season) can lead to an extension of construction time and hence result in more cost-intensive provisioning of equipment and materials.

Construction delays, which have to be mitigated later through measures that accelerate certain construction phases (e. g. by simultaneous production of work segments initially designed to be produced in sequence) result in excess requirements of equipment, personnel, or formwork materials, which then cannot be used repeatedly.

Contractual penalties or damage claims can follow failure to meet the contractually agreed deadlines. Due to these reasons, the scrupulous creation of a construction schedule plays an important role as the basis for later calculations. Identifiable influences, such as traffic routing, testing periods, or post-production services have to be considered when evaluating duration and schedule allocation of individual work phases. In any case, adequate buffer periods should be planned to account for unanticipated events.

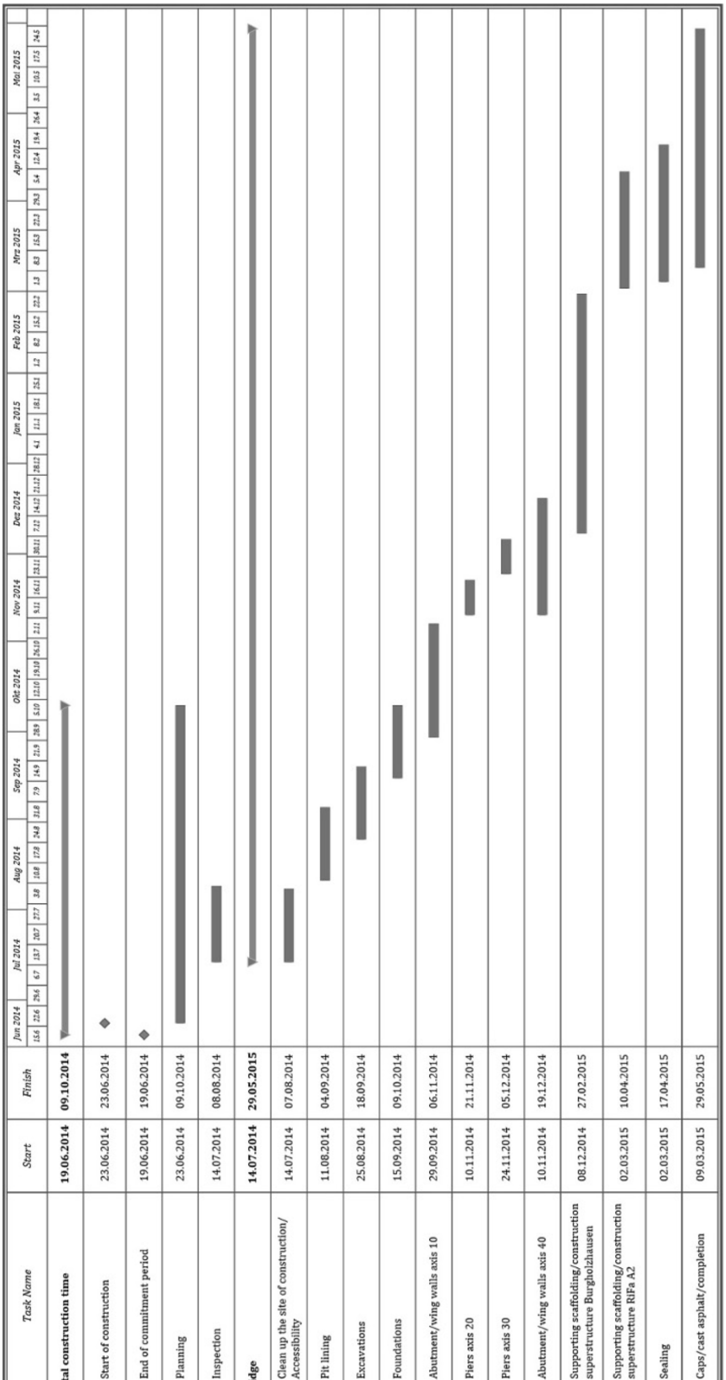

Figure 2.11 Construction schedule of the steel composite bridge

2.4.3.3 Costing and pricing

Construction site facilities and auxiliary structures
Costs involved for the construction site facilities commonly amount to 5 to 10 % of the total construction sum. Optimized establishing logistics are indispensable in order to process an economic bid price. The determination of costs is dependent on the arrangement of facilities, equipment, access roads, etc. Here, interdependencies can be observed through the compilation of a construction site establishment schedule.

In the field of construction engineering, auxiliary structures are of special significance. They include, for example, formwork, scaffolds, timber structures, parapets, and others. Costs for auxiliary structures have to be determined and allocated to existing service items separately as respective items are usually not included in the bill of quantities for auxiliary structures. Cost bases, in this case, constitute the preliminary structural analyses by the client, the draft design, and the determination of quantities. The extent to which costs for auxiliary structures are included in existing service items is detailed in the respective contract.

Subcontractors and suppliers
Prior to the calculation, it has to be determined which construction phases are realized by the contractor and which by subcontractors.

Subcontractor services are required whenever work phases cannot be realized by the contracted company, which can be potentially due to professional reasons (specialist groups) or lack of capacities (personnel and equipment) at the time of the service. A professional invitation of subcontractors and price inquiries, respectively, are required for an orderly subcontractor calculation. And, in any case, contract conditions provided by the client have to be transferred to involved subcontractors. Furthermore, conditions specific to the construction site as well as ancillary engineering conditions (access roads, distances, space allocation, etc.) have to be provided. Naturally, construction times for individual subcontractors, which are detailed in the construction schedule, have to be arranged as well. Binding periods and potential price changes during the agreed construction time have to be arranged with the subcontractor in such a way that the binding period of the contractor and client is not negatively affected. Declarations demanded by the client (declaration of commitment, minimum wage, reliability, etc.) have to also be demanded from all subcontractors.

Table 2.22 List of subcontractors of the prestressed concrete bridge

Ordinal No.	Short description	Sub.
0. 1. 1.	Stability survey	Engineering office
0. 1. 2.	As-built drawings	Engineering office
0. 2. 4.	Long-term road safety	Sub. traffic safety
0. 3. 1.	Clearing of construction area	Sub. earthworks
0. 3. 2.	Remove construction	Sub. earthworks

0. 3. 3.	Excavation of topsoil	Sub. earthworks
0. 3. 4.	Excavation of topsoil and covering	Sub. earthworks
0. 3. 5.	Draining layer near structure	Sub. earthworks
0. 3. 6.	Transport and integration of material as backfilling	Sub. earthworks
0. 3. 7.	Transport and integration of material	Sub. earthworks
0. 3. 8.	Layer of freeze-proof material	Sub. earthworks
0. 3. 9.	Transport and integration of material	Sub. earthworks
0. 3. 10.	Layer of freeze-proof material	Sub. earthworks
0. 3. 11.	Asphalt base course of AC 32 T S	Sub. earthworks
0. 3. 12.	Cleaning of base	Sub. earthworks
0. 3. 13.	Spray-coating of bituminous emulsion	Sub. earthworks
0. 3. 14.	Asphalt surface of AC 11 D S	Sub. earthworks
0. 3. 15.	Alignment with brook profile	Sub. earthworks
0. 4. 1.	Equipment operation for steel pile walls	Sub. special foundation engineering
0. 4. 2.	Steel pile wall	Sub. special foundation engineering
0. 4. 3.	Establishment of construction pit	Sub. earthworks
0. 4. 5.	Compacting of foundation base	Sub. earthworks
0. 4. 6.	Transport and integration of pit ground materials	Sub. earthworks
0. 4. 7.	Equipment operation for steel pile walls	Sub. special foundation engineering
0. 4. 8.	Steel pile wall	Sub. special foundation engineering
0. 4. 9.	Establishment of construction pit	Sub. earthworks
0. 4. 11.	Transport and integration of pit ground materials	Sub. earthworks
0. 4. 12.	Cutting of steel pile wall	Sub. special foundation engineering
0. 4. 13.	Crew for removal of obstructions	Sub. special foundation engineering
0. 5. 19.	Assembly of falsework	Sub. falsework
0. 5. 28.	Install prestressed steel	Sub. prestressed steel
0. 5. 38.	Preparation of concrete base	Sub. structural sealing
0. 5. 39.	Application of ground coat to concrete base	Sub. structural sealing
0. 5. 40.	Supply of epoxy resin	Sub. structural sealing
0. 5. 41.	Creation of sealing layer as bituminous sheeting	Sub. structural sealing
0. 5. 42.	Install sealing sleeve	Sub. structural sealing

0. 5. 43.	Install reinforcing strips	Sub. structural sealing
0. 5. 44.	Install reinforcing strips	Sub. structural sealing
0. 5. 45.	Install sealing sleeve	Sub. structural sealing
0. 5. 46.	Creation of protective layer	Sub. structural sealing
0. 5. 57.	Creation of asphalt protection layer	Sub. structural sealing
0. 5. 58.	Processing of melted asphalt surface	Sub. structural sealing
0. 5. 59.	Creation of junction as joint	Sub. structural sealing

In order to prepare the calculation for services rendered by the contractor, an overview of suppliers of required materials (e. g. concrete), which are processed by the contracted company, is sensible. To this end, a consolidation list can be used in the same vein as subcontracted services. Technical supply conditions for required materials (bill of quantities, construction specifications) are defined in the contract and have to be obliged without exception. Both contractual conditions provided by the client that affect material supply (quality, composition, etc.) and ancillary conditions specific to the construction site (access roads, distances, space allocation, etc.) have to be relayed to the supplier together with the price inquiry. Furthermore, the congruence of the binding periods with respect to both client and supplier has to be observed. For longer construction times (e. g. concrete supply for parapets in a year's time at the earliest), the period of offer validity has to be arranged with the supplier accordingly.

Determination of the average wage

Determination of the average wage value specific to the construction site is indispensable for a reliable calculation. The following example shows one possibility of rough estimating, in which actual wage rates and premiums (based on respective union and state agreements) are variable. The composition of involved construction crews (foremen, blue-collar employees, etc.) has to be adjusted according to actual requirements as well. If needed, additional employees (machine operators, carpenters, etc.) have to be involved. A separate average wage value should be determined for specialist groups provided they operate within the contracted company.

In the following example, the crew consists of managing foreman at 18.19 €/h and four blue-collar workers at 14.50 €/h each resulting in an average union wage of 15.24 €/h. Subsequent calculation steps are as follows:

Union wage		15.24 €/h
Transport of personnel		1.86 €/h
Year-end bonus	93 x 13.42 €/h/(173 h x 12 months - 30 leave days x 8 h)	0.68 €/h
Employee savings bonus		0.26 €/h
Social wage (special leave)	(15.24 €/h + 0.5 x 15.24 €/h) x 8/1836 h/a	0.10 €/h

Public holiday pay	7 holidays p.a. x 8 h/day x 15.24 €/h/1836 h/a	0.46 €/h
Paid sick leave	7 paid sick leave days p. a. x 8 h/day x 15.24 €/h/1836 h/a	0.46 €/h
Union wage increase	2.3 % x 50 % construction time x 15.24 €/h	0.18 €/h
Total		**19.24 €/h**
Complementary pension insurance leave		15.8 %
Complementary pension insurance wage adjustment		1.6 %
Complementary pension insurance reimbursement of prof. training		1.2 %
Winter construction levy	Client share: 100 %	1.0 %
Pension insurance	Client share: 50 %	9.8 %
Unemployment insurance	Client share: 50 %	3.3 %
Health insurance	Client share: 50 %	7.4 %
Nursing care insurance	Client share: 50 %	0.9 %
Provision of company capital	Client share: 100 %	10.0 %
Total		50.9 %
50.9 % of 19.24 €/h		9.78 €/h*)
*) calculation with exact values		
Social insurance for vacation leave	21.05 % x 30 x 8 h vacation x 15.24 €/h/1,836 h/a	0.42 €
Equalization fee [€/h][57]	40K € for 300,000 h	0.13 €
Individual contribution for prof. training	60K € for 300,000 h	0.20 €
Liability insurance	70K € for 300,000 h	0.23 €
Total €/h		0.98 €
Calculated average wage		30.00 €
Daily allowance for expenses	34 € per day at 8 h	4.25 €
Calculated average wage plus above		**34.25 €**

Determination of costings

The following cost elements are determined for each partial service:

Wage costs

- Average wage
- Efficiency factor

Material costs

- Contractor (available resources) material costs
- Material purchase costs
- Integration materials
- Reutilizable materials

Equipment costs

- Efficiency factor
- Contractor equipment costs
- Third-party equipment costs

Subcontractor costs

Wage and equipment costs are the result of multiplying the average wage value and hourly rate for the equipment in question respectively by the efficiency factor. The efficiency factor for wages and equipment is calculated as the quotient of time expenditure and quantity unit. The approach towards the required time expenditure for a partial service is based on experience values, which can be determined through, for example, post-calculations for similar construction projects. In lieu of own experience values, professional literature can be consulted. In any case, determining the efficiency factor is a significant criterion for pricing and should hence always be adjusted in accordance with the specific conditions of the construction project. The efficiency factor is comparatively smaller in conjunction with simple constructions, such as even, vertical formwork for a foundation, and larger for complicated structures such as abutment with timber-board formwork, false edges, and cantilevers.

Material costs entail either company-internal costs for own materials or material purchase costs. Respective transport costs to the construction site have to be considered for own materials. Prices for purchased materials usually include free delivery to the construction site. If the used material becomes a permanent component of the structure, 100 % of the costs have to be entered into the calculation whereas for temporary materials (e. g. groove-and-tongue piles for temporary formwork or sheathing timber), the price can be reduced by a certain factor that correlates to the number of potential reutilizations of the materials until the definitive end of the material's wear lifespan. For a massive tongue-and-groove pile used for the temporary lining of a construction pit that can subsequently be removed again, assuming a decuple reutilization, the related factor would amount to 0.1 for example. However, additional costs for removal

57) In Germany, a mandatory fee for companies that do not employ a certain number of severely handicapped persons.

and transport of the pile are accrued for a thusly reduced material price that have to be considered. Since, the employed material quantity does not necessarily correspond to the calculated quantity listed in the respective service item, quantity projections have to be determined accordingly. For example, in order to produce 1 m^3 of concrete including formwork, 1 m^2 of formwork, 1 m^3 of concrete, and 1 kg of curing material can be required.

Subcontractor costs are determined through the bid price of the respected subcontractor. If the subcontractor price for a service item meets the requirements of the client, the standard price of the subcontractor equals the subcontractor costs of the service item. In contrast, if the standard price of the subcontractor covers the service item partially, it is necessary to determine the subcontractor costs of the service item through several sub-items, which entail standard rates of further subcontractors or further contractor costs.

Individual costs of partial services are determined for each item in the bid by determining and combining costs for the cost elements above, which may entail further sub-items. Figure 2.12 shows an example subcontractor cost calculation for the bid item “concrete including formwork”.

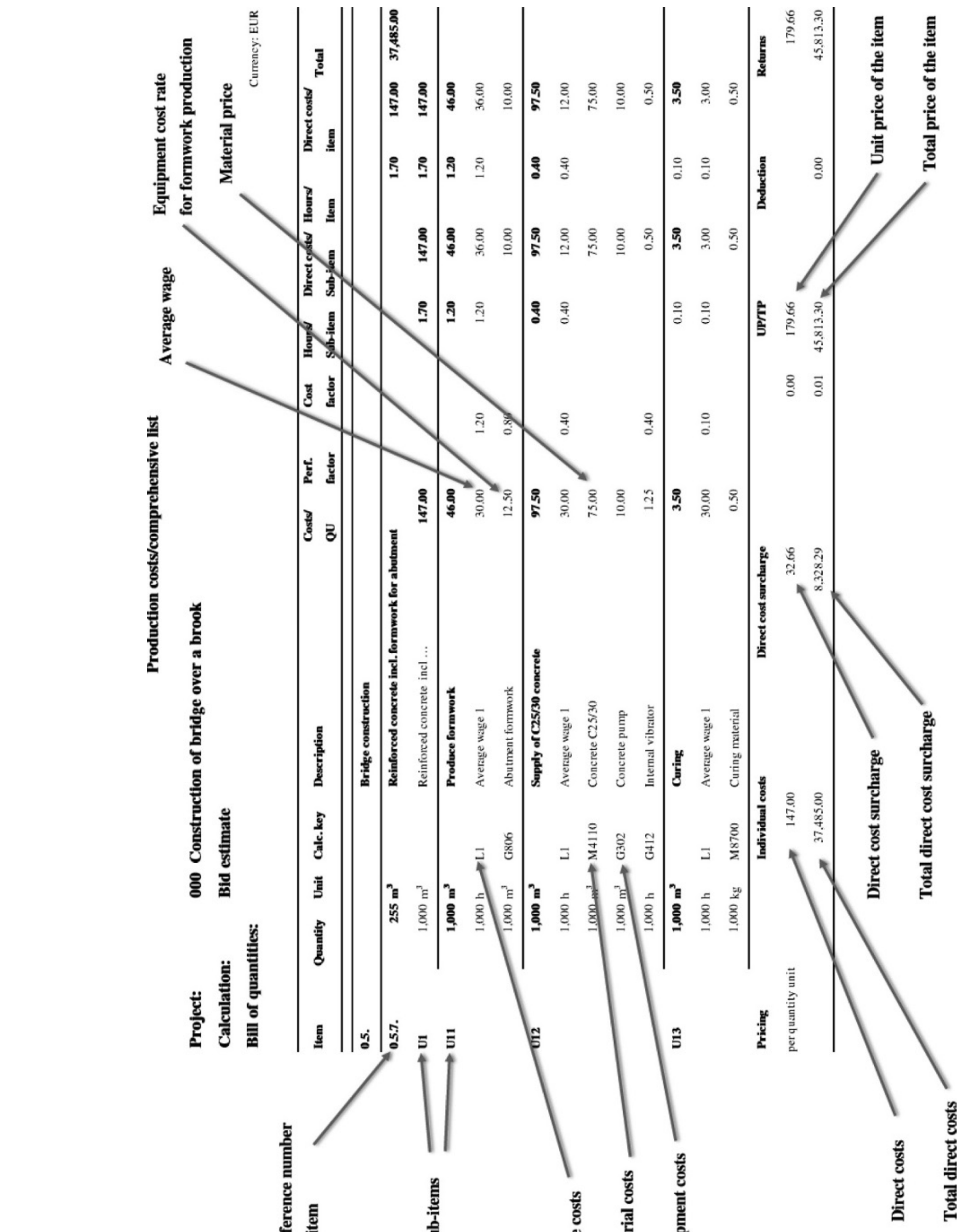

Figure 2.12 Example of a direct cost calculation

Another component towards the total costs for partial services are site overheads, which are calculated - depending on the specifications set by the client - either as part of the service item “construction site establishment” or in a separate bill of quantities containing the construction site overhead costs. Calculating them as part of the service item “construction site establishment” enables a transparent representation of costs independent from the quantities billed at a later time. Whereas using the latter method, construction site overhead costs are allocated to all bid items as a percentage and means a direct dependence on total quantities. Thus, later changes to billed quantities also change yield values for construction site overhead costs. Major components of construction site overhead costs are time-dependent costs such as:

- Construction management personnel
- Foreman
- Crane operator
- Crane provisioning
- Provisioning of site containers
- Electricity supply
- Water supply

Costs for management and foreman, in this case, can be calculated as part of the item “construction site establishment.” Table 2.23 shows an example bill of quantities for item “construction site establishment” (item 1.1 in the bill of quantities) containing the calculation components above.

After determining production costs that are composed of the individual costs of partial services and the site overhead cost, general overheads are allocated to the total bid sum. They entail any costs of the construction company which are not directly related to the construction project and have to be determined, at least annually, on the basis of the company’s planning and capacity.

General overhead costs entail, among others, costs for the company location, administration, engineering administration, management, etc. The sum of these costs is divided by the company’s estimated yearly service. Hence, assuming a yearly total of 3.2 million EUR general overhead and a total of 40 million EUR yearly construction service, the required allocation value that has to be applied to the total bid sum of every bid amounts to (3.2 million EUR / 40 million EUR) = 8 %. Thus, if the production costs for a project amount to 291,830 EUR, 25,940 EUR general overhead costs have to be allocated, which corresponds to 8.89 % of production costs to the amount of 291,830 EUR or 8 % of the total bid sum to the amount of 324,255 EUR, respectively.

Allocation of the value for risk and reward, which changes according to project difficulty and market requirements, is performed in the same manner. For the example herein, a surcharge of 2 % is applied to the total bid sum, which equate to 2.22 % of the production costs.

The following tables show an example cumulative calculation including subcontractor, construction site overhead and general overhead costs as well as risk and reward using selected bid items. Table 2.25 shows the complete calculation, Table 2.26 shows the bid overview, and Table 2.27 the complete bill of quantities.

Table 2.23 Calculation of the item „Construction site facilities" of the prestressed concrete bridge

Production costs/comprehensive list

Project: **000 Construction of bridge over a brook**
Calculation: **Bid estimate** **Currency: EUR**
Bill of quantities:

Item	Quantity	Quantity unit	Calc. key	Description	Costs/ QU	Perf. factor	Cost factor	Hour/ sub-item	Direct costs/ sub-item	Hours/ item	Direct costs/item	Total
0				Bridge Construction								
0.2.				Construction site facilities								
0.2.1.	1.00	ea		Establishing & provisioning of site						273.00	154,674.90	154,674.90
U1	1.00	ea		Site setup	154,674.90			273.00	154,674.90	273.00	154,674.90	
U11	1.00	h		Establishing of site	887.20			8.00	887.20	8.00	887.20	
	8.00	h	L1	Average wage 1	30.00			8.00	240.00	8.00	240.00	
	approx. quantity: 8											
	215.20	l	B10	Diesel fuel	1.00				215.20		215.20	
	approx. quantity: 269 x 0.1 x 8											
	8.00	h	G706	Flat bed trailer	29.00				232.00		232.00	
	approx. quantity: 8											
	8.00	h	G711	Tractor unit 269 kW	25.00				200.00		200.00	
	approx. quantity: 8											
U12	**200**	**m2**		**Preparation of area/site road**	**12.76**			**0.27**	**12.76**	**54.00**	**2,551.50**	
	0.27	h	L1	Average wage 1	30.00			0.27	8.10	54.00	1,620.00	
	0.30	t	M1303	Mineral aggregate mix	9.10				2.73		546.00	
	approx. quantity: 0.3											
	0.24	l	B10	Diesel fuel	1.00				0.24		48.00	
	approx. quantity: 48 x 0.1 x 0.05											
	0.40	l	B10	Diesel fuel	1.00				0.40		80.00	
	approx. quantity: 80 x 0.1 x 0.05											
	0.05	h	G207	48-kW wheel loader "ZL 8 B"	6.25				0.31		62.50	
	approx. quantity: 0.05											
	0.05	h	G703	80-kW, 8-t truck	19.50				0.98		195.00	
	approx. quantity: 0.05											
U13	**1.00**	**ea**		**Electricity supply**	**240.00**			**8.00**	**240.00**	**8.00**	**240.00**	
	8.00	h	L1	Average wage 1	30.00			8.00	240.00	8.00	240.00	
	approx. quantity: 8											
	1.00		M95101	Cable								
U14	**1.00**	**ea**		**Water supply**	**240.00**			**8.00**	**240.00**	**8.00**	**240.00**	
	8.00	h	L1	Average wage 1	30.00			8.00	240.00	8.00	240.00	
	approx. quantity: 8											
	1.00		M00	Other materials								
U15	**1.00**	**ea**		**Site container**	**90.00**			**2.00**	**90.00**	**2.00**	**90.00**	
	1.00	h	L1	Average wage 1	30.00	2.00		2.00	60.00	2.00	60.00	

Production costs/comprehensive list

Project: **000 Construction of bridge over a brook**
Calculation: **Bid estimate** **Currency: EUR**
Bill of quantities:

Item	Quantity	Quantity unit	Calc. key	Description	Costs/ QU	Perf. factor	Cost factor	Hour/ sub-item	Direct costs/ sub-item	Hours/ item	Direct costs/item	Total
	1.00	Ltr	B10	Diesel fuel	1.00				10.00			
	approx. quantity: 100 x 0.1											
	1.00	h	G3005	100-kW mobile crane “LIEBHERR”	20.00				20.00		20.00	
	approx. quantity: 1											
U16	**1.00**	**ea**		**Site lighting**	**30.00**			**1.00**	**30.00**	**1.00**	**30.00**	
	8.00	h	L1	Average wage 1	30.00			1.00	30.00	1.00	30.00	
	approx. quantity: 1											
	1.00		M00	Other materials								
U17	**200**	**m**		**Site safety**	**14.11**			**0.10**	**14.11**	**20.00**	**2,821.00**	
	approx. quantity: 200											
	0.10	h	L1	Average wage 1	30.00			0.10	3.00	20.00	600.00	
	approx. quantity: 0.1											
	1.00	m	M9102	Timber fence	10.00				10.00		2,000.00	
	0.48	l	B10	Diesel fuel	1.00				0.48		96.00	
	approx. quantity: 48 x 0.1 x 0.05											
	0.10	h	G207	48-kW wheel loader “ZL 8 B”	6.25				0.63		125.00	
	approx. quantity: 0.1											
U18	**1.00**	**ea**		**Assembly of tower crane**	**2,500.00**				**2,500.00**		**2,500.00**	
	1.00		G3009	Crane provider	2,500.00				2,500.00		2,500.00	
U19	**1.00**	**ea**		**Operation of mobile rotary crane**	**6,000.00**			**100,000.00**	**6,000.00**	**100,000.00**	**6,000.00**	
	100.00	h	L1	Average wage 1	30.00			100,000.00	3,000.00	100,000.00	3,000.00	
	approx. quantity: 100											
	1,000.00	l	B10	Diesel fuel	1.00				1,000.00		1,000.00	
	approx. quantity: 100 x 0.1 x 100											
	100.00	h	G3005	100-kW mobile crane “LIEBHERR”	20.00				2,000.00		2,000.00	
	approx. quantity: 100											
U1a	**1.00**	**ea**		**Transport of formwork**	**2,635.20**			**16.00**	**2,635.20**	**16.00**	**2,635.20**	
	16.00	h	L1	Average wage 1	30.00			16.00	480.00	16.00	480.00	
	approx. quantity: 2 x 8											
	1,291.20	l	B10	Diesel fuel	1.00				1,291.20		1,291.20	
	approx. quantity: 269 x 0.3 x 2 x 8											
	16.00	h	G706	Flat bed trailer	29.00				464.00		464.00	
	approx. quantity: 2 x 8											
	16.00	h	G711	Tractor truck 269 kW	25.00				400.00		400.00	
	approx. quantity: 2 x 8											

Production costs/comprehensive list

Project: **000 Construction of bridge over a brook**
Calculation: **Bid estimate** **Currency: EUR**
Bill of quantities:

Item	Quantity	Quantity unit	Calc. key	Description	Costs/QU	Perf. factor	Cost factor	Hour/sub-item	Direct costs/sub-item	Hours/item	Direct costs/item	Total
U1b	**1.00**	**ea**		**Quality verification**	**980.00**			**16.00**	**980.00**	**16.00**	**980.00**	
	16.00	h	L1	Average wage 1	30.00			16.00	480.00	16.00	480.00	
	approx. quantity: 16											
	1.00		S802	Quality verification	500.00				500.00		500.00	
U1c	**1.00**	**ea**		**Surveys**	**2,980.00**			**16.00**	**2,980.00**	**16.00**	**2,980.00**	
	16.00	h	L1	Average wage 1	30.00			16.00	480.00	16.00	480.00	
	approx. quantity: 16											
	1.00		S804	Surveys	2,500.00				2,500.00		2,500.00	
U1d	**1.00**	**ea**		**Traffic safety**	**3,000.00**				**3,000.00**		**3,000.00**	
	1.00		S63	Traffic safety	3,000.00				3,000.00		3,000.00	
U1e	**1.00**	**ea**		**Construction operations during winter**	**1,220.00**			**24.00**	**1,220.00**	**24.00**	**1,220.00**	
	24.00	h	L1	Average wage 1	30.00			24.00	720.00	24.00	720.00	
	approx. quantity: 24											
	1.00		S606	Construction operations during winter	500.00				500.00		500.00	
U1f	**1.00**	**ea**		**Design costs**								
	1.00		S801	Design/scheduling services								
U1g	**1.00**	**ea**		**Subcontractor**	**1,000.00**				**1,000.00**		**1,000.00**	
	1.00		7	Subcontractor	1,000.00				1,000.00		1,000.00	
U1l	**1.00**	**ea**		**Management, foreman, administration**	**127,500.00**				**127,500.00**		**127,500.00**	
	180.00	d	L3	Site manager	400.00				72,000.00		72,000.00	
	approx. quantity: 9 x 20											
	140.00	d	L2	Foreman	300.00				42,000.00		42,000.00	
	approx. quantity: 7 x 20											
	180.00	d	L4	Administration	250.00				13,500.00		13,500.00	
	approx. quantity: 9 x 20											
Pricing		**Direct costs**		**Direct cost surcharge**				**UP/TP**		**Deduction**		**Returns**
per qty. unit		154,674.90		34,365.13		0.00		189,040.03				189,040.03
		154,674.90		34,365.13		0.00		189,040.03				189,040.03

Table 2.24 Bill of quantities for site overheads of the prestressed concrete bridge

Production costs / comprehensive list

Project: 000 Construction of bridge over a brook
Calculation: Bid estimate — **Currency: EUR**
Bill of quantities:

Item	Quantity	Quantity unit	Calc. key	Description	Costs/ QU	Perf. Factor	Cost factor	Hours/ sub-item	Direct costs/ sub-item	Hours/ item	Direct costs/item	Total
				***standard rates apply								
..10.	**1.00**	**ea**		**Site provisioning**							**26,520.00**	**26,520.00**
U1	**1.00**			**Site provisioning**	**26,520.00**				**26,520.00**		**26,520.00**	
U1h	**1.00**	**ea**		**Accomodation / off. / etc.**	**2,100.00**				**2,100.00**		**2,100.00**	
	200.00	d	G610	Container 6 m	18,415.00				1,300.00		1,300.00	
	approx. quantity: 20 x 10											
	200.00	d	G611	Container 3 m	4				800.00		800.00	
	approx. quantity: 20 x 10											
U1i	**1.00**	**ea**		**Fueling system (prov.)**	**400.00**				**400.00**		**400.00**	
	160	d	G910	Fueling system	2.50				400.00		400.00	
	approx. quantity: 20 x 8											
U1j	**1.00**	**ea**		**Telecommunication**	**500.00**				**500.00**		**500.00**	
	1.00		61	Telecommunication	500.00				500.00		500.00	
U1k	**1.00**	**ea**		**Mobile rotary crane (prov.)**	**12,000.00**				**12,000.00**		**12,000.00**	
	8.00	mos.	G3009.1	Crane provider	1,500.00				12,000.00		12,000.00	
	approx. quantity: 8											
U1m	**1.00**	**ea**		**Site operation**	**11,520.00**				**11,520.00**		**11,520.00**	
	240.00	d	G1303	Emergency generator	16.00				3,840.00		3,840.00	
	approx. quantity: 8 x 30											
	7,680.00	l	B10	Diesel fuel	1.00				7,680.00		7,680.00	
	approx. qty: 60 x 0.1 x 8 x 20 x 8											
Pricing		**Direct costs**										
per qty. Unit			26,520.00									
			26,520.00									
2				**Site overhead bill of quantities**								
Main cost types, Debit+Risk			**Key**	**Description**					**Costs**			
			3	Auxiliary & operating material costs					7,680.00			
			5	Equipment costs					18,340.00			
			6	Misc.					500			
			Total						**26,520.00**			
			Hours:									
			Production costs									
			26,520.00									

Table 2.25 Calculation printout of the prestressed concrete bridge

Production costs/comprehensive list

Project: 000 Construction of bridge over a brook

Calculation: Bid estimate

Currency: EUR

Bill of quantities:

Item	Quantity	Quantity unit	Calc. key	Description	Costs/QU	Per. factor	Cost fac.	Hours/sub-item	Direct costs/sub-item	Hours/item	Direct costs/item	Total
0				**Bridge construction**								
0.2.				**Construction site facilities**								
0.2.1.	**1.00**	**ea**		**Establishing & provisioning of site**						**273.00**	**154,674.90**	**154,674.90**
U1	**1.00**	**ea**		**Establishing of site**	**154,674.90**			**273.00**	**154,674.90**	**273.00**	**154,674.90**	
U11	1.00	ea		**Establishing of site**	**887.20**			8.00	887.20	8.00	887.20	
	8.00	h	L1	Average wage1	30.00			8.00	240.00	8.00	240.00	
	approx. quantity: 8											
	215.20	l	B10	Diesel fuel	1.00				215.20		215.20	
	approx. quantity: 269 x 0.1 x 8											
	8.00	h	G706	Flat bed trailer	29.00				232.00		232.00	
	approx. quantity: 8											
	8.00	h	G711	Tractor truck 269 KW	25.00				200.00		200.00	
	approx. quantity: 8											
U12	**200.000**	**m2**		**Preparation of area/site road**	**12.76**			**0.27**	**12.76**	**54.00**	**2,551.50**	
	0.27	h	L1	Average wage1	30.00			0.27	8.10	54.00	1,620.00	
	0.30	t	M1303	Mineral aggregate mix	9.10				2.73		546.00	
	approx. quantity: 0.3											
	0.24	l	B10	Diesel fuel	1.00				0.24		48.00	
	approx. qty: 48 x 0.1 x 0.05											
	0.40	l	B10	Diesel fuel	1.00				0.40		80.00	
	approx. qty: 80 x 0.1 x 0.05											
	0.05	h	G207	48-kW wheel loader “ZL 8 B”	6.25				0.31		62.50	
	approx. quantity: 0.05											
	0.05	h	G703	80-kW, 8-t truck	19.50				0.98		195.00	
	approx. quantity: 0.05											
U13	**1.00**	**ea**		**Electricity supply**	**240.00**			**8.00**	**240.00**	**8.00**	**240.00**	
	8.00	h	L1	Average wage1	30.00			8.00	240.00	8.00	240.00	
	approx. quantity: 8											
	1.00		M95101	Cable								
U14	**1.00**	**ea**		**Water supply**	**240.00**			**8.00**	**240.00**	**8.00**	**240.00**	
	8.00	h	L1	Average wage1	30.00			8.00	240.00	8.00	240.00	
	approx. quantity: 8											
	1.00		M00	Other materials								

Production costs/comprehensive list

Project: **000 Construction of bridge over a brook**
Calculation: **Bid estimate** **Currency: EUR**
Bill of quantities:

Item	Quantity	Quantity unit	Calc. key	Description	Costs/ QU	Per. factor	Cost fac.	Hours/ sub-item	Direct costs/sub-item	Hours/ item	Direct costs/item	Total
U15	**1.00**	**ea**		**Assembly of containers**	**90.00**			**2.00**	**90.00**	**2.00**	**90.00**	
	1.00	h	L1	Average wage1	30.00	2.00		2.00	60.00	2.00	60.00	
	approx. quantity: 1											
	10.00	l	B10	Diesel fuel	1.00				10.00		10.00	
	approx. quantity: 100 x 0.1											
	1.00	h	G3005	100-kW mobile rotary crane “LIEBHERR”	20.00				20.00		20.00	
	approx. quantity: 1											
U16	**1.00**	**ea**		**Site lighting**	**30.00**			**1.00**	**30.00**	**1.00**	**30.00**	
	8.00	h	L1	Average wage1	30.00			1.00	30.00	1.00	30.00	
	approx. quantity: 1											
	1.00		M00	Other materials								
U17	**200.00**	**m**		**Site safety**	**14.11**			**0.10**	**14.11**	**20.00**	**2,821.00**	
	approx. quantity: 200											
	0.10	h	L1	Average wage1	30.00			0.10	3.00	20.00	600.00	
	approx. quantity: 0.1											
	1.00	m	M9102	Timber fence	10.00				10.00		2,000.00	
	0.48	l	B10	Diesel fuel	1.00				0.48		96.00	
	approx. qty: 48 x 0.1 x 0.05											
	0.10	h	G207	48-kW wheel loader “ZL 8 B”	6.25				0.63		125.00	
	approx. quantity: 0.1											
U18	**1**	**ea**		**Assembly of tower crane**	**2,500.00**				**2,500.00**		**2,500.00**	
	1.000		G3009	Crane provider	2,500.00				2,500.00		2,500.00	
U19	**1**	**ea**		**Mobile crane operation**	**6,000.00**			**100.00**	**6,000.00**	**100.00**	**6,000.00**	
	100.00	h	L1	Average wage1	30.00			100.00	3,000.00	100.00	3,000.00	
	approx. quantity: 100											
	1,000.00	l	B10	Diesel fuel	1.00				1,000.00		1,000.00	
	approx. qty: 100 x 0.1 x 100											
	100.00	h	G3005	100-kW mobile crane “LIEB-HERR”	20.00				2,000.00		2,000.00	
	approx. quantity: 100											
U1a	**1.00**	**ea**		**Transport of formwork**	**2,635.20**			**16.00**	**2,635.20**	**16.00**	**2,635.20**	
	16.00	h	L1	Average wage1	30.00			16.00	480.00	16.00	480.00	
	approx. quantity: 2 x 8											
	1291.20	l	B10	Fuel Diesel	1.00				1,291.20		1,291.20	
	approx. qty: 269 x 0.3 x 2 x 8											

Production costs/comprehensive list

Project: **000 Construction of bridge over a brook**
Calculation: **Bid estimate** **Currency: EUR**
Bill of quantities:

Item	Quantity	Quantity unit	Calc. key	Description	Costs/ QU	Per. factor	Cost fac.	Hours/ sub-item	Direct costs/sub-item	Hours/ item	Direct costs/item	Total
	16.00	h	G706	Flat bed trailer	29.00				464.00		464.00	
	approx. quantity: 2 x 8											
	16.00	h	G711	Tractor truck 269 KW	25.00				400.00		400.00	
	approx. quantity: 2 x 8											
U1b	**1.00**	**ea**		**Quality verification**	**980.00**			**16.00**	**980.00**	**16.00**	**980.00**	
	16.00	h	L1	Average wage1	30.00			16.00	480.00	16.00	480.00	
	approx. quantity: 16											
	1.00		S802	Quality verification	500.00				500.00		500.00	
U1c	**1.00**	**ea**		**Surveys**	**2,980.00**			**16.00**	**2,980.00**	**16.00**	**2,980.00**	
	16.00	h	L1	Average wage1	30.00			16.00	480.00	16.00	480.00	
	approx. quantity: 16											
	1.00		S804	Surveys	2,500.00				2,500.00		2,500.00	
U1d	**1.00**	**ea**		**Traffic safety**	**3,000.00**				**3,000.00**		**3,000.00**	
	1.00		S63	Traffic safety	3,000.00				3,000.00		3,000.00	
U1e	**1.00**	**ea**		**Constr. during winter**	**1,220.00**			**24.00**	**1,220.00**	**24.00**	**1,220.00**	
	24.00	h	L1	Average wage1	30.00			24.00	720.00	24.00	720.00	
	approx. quantity: 24											
	1.00		S606	Construction during winter	500.00				500.00		500.00	
U1f	**1.00**	**ea**		**Scheduling costs**								
	1.00		S801	Engineering per./scheduling								
U1g	**1.00**	**ea**		**Subcontractors**	**1,000.00**				**1,000.00**		**1,000.00**	
	1.00		7	Subcontractors	1,000.00				1,000.00		1,000.00	
U1l	**1.00**	**ea**		**Management, foreman, administration**	**127,500.00**				**127,500.00**		**127,500.00**	
	180.00	d	L3	Construction manager	400.00				72,000.00		72,000.00	
	approx. quantity: 9 x 20											
	140.00	d	L2	Foreman	300.00				42,000.00		42,000.00	
	approx. quantity: 7 x 20											
	180.00	d	L4	Administration	250.00				13,500.00		13,500.00	
	approx. quantity: 9 x 20											
Pricing		**Direct costs**		**Direct cost surcharge**				**UP/TP**			**Deduction**	**Returns**
per qty. unit		154,674.90		34,365.13		0.00		189,040.03				189,040.03
		154,674.90		34,365.13		0.00		189,040.03				189,040.03

Production costs/comprehensive list

Project: 000 Construction of bridge over a brook

Calculation: Bid estimate — **Currency: EUR**

Bill of quantities:

Item	Quantity	Quantity unit	Calc. key	Description	Costs/ QU	Per. factor	Cost fac.	Hours/ sub-item	Direct costs/sub-item	Hours/ item	Direct costs/item	Total
0.2.2.	**1.00**	**ea**		**Clearing of site**						**32.00**	**2,599.20**	**2,599.20**
U1	**1.00**	**ea**		**Clearing of site**	**2,599.20**			**32.00**	**2,599.20**	**32.00**	**2,599.20**	
U11	**1.00**	**ea**		**Clearing of site**	**2,599.20**			**32.00**	**2,599.20**	**32.00**	**2,599.20**	
	16.00	h	L1	ML1	30.00	2.00		32.00	960.00	32.00	960.00	
	approx. quantity: 2 x 8											
	16.00	h	G706	Flat bed trailer	29.00				464.00		464.00	
	approx. quantity: 2 x 8											
	16.00	h	G711	Tractor truck 269 KW	25.00				400.00		400.00	
	approx. quantity: 2 x 8											
	16.00	h	G3005	100-kW mobile rotary crane "LIEBHERR"	20.00				320.00		320.00	
	approx. quantity: 2 x 8											
	455.20	l	B10	Diesel fuel	1.00				455.20		455.20	
	approx. qty: 269 x 0.1 x 2 x 4 + 100 x 0.3 x 2 x 4											
Pricing		**Direct costs**		**Direct cost surcharge**				**UP/TP**			**Deduction**	**Returns**
per qty. unit		2,599.20		577.48		0.00		3,176.68				3,176.68
		2,599.20		577.48		0.00		3,176.68				3,176.68
0.2. Construction site facilities												
Main cost types, Debit+Risk			**Key**	**Description**					**Costs**			
			1	Personnel costs					136,650.50			
			2	Materials					2,546.00			
			3	Auxiliary and operating materials					3,195.60			
			5	Equipment costs					7,382.50			
			7	Subcontractors					7,500.00			
			Total						157,274.10			
			Hours						305,000.00			
		Direct costs		**Direct cost surcharge**					**UP/TP**		**Deduction**	**Returns**
		157,274.10		34,942.61			0.00		192,216.71			192,216.71

Production costs/comprehensive list

Project: **000 Construction of bridge over a brook**
Calculation: **Bid estimate** **Currency: EUR**
Bill of quantities

Item	Quantity	Unit	Calc. key	Description	Costs/ QU	Per. factor	Cost fac.	Hours/ sub-item	Direct costs/sub-item	Hours/ item	Direct costs/item	Total
0.5.				**Bridge Construction**								
0.5.7.	**255.00**	**m3**		**Prod. of abutment reinf. c. & formwork**						**1.70**	**147.00**	**37,485.00**
U1	**1.00**	**m3**		**Prod. of abutment ...**	**147.00**			**1.70**	**147.00**	**1.70**	**147.00**	
U11	**1.00**	**m3**		**Production of formwork**	**46.00**			**1.20**	**46.00**	**1.20**	**46.00**	
	1.00	h	L1	Average wage 1	30.00	1.20		1.20	36.00	1.20	36.00	
	1.00	m3	G806	Abutment formwork	12.50	0.80			10.00		10.00	
U12	**1.00**	**m3**		**Supply of C25/30 concrete**	**97.50**			**0.40**	**97.50**	**0.40**	**97.50**	
	1.00	h	L1	Average wage 1	30.00	0.40		0.40	12.00	0.40	12.00	
	1.00	m3	M4110	Concrete C25/30	75.00				75.00		75.00	
	1.00	m3	G302	Concrete pump	10.00				10.00		10.00	
	1.00	h	G412	Internal vibrator	1.25	0.40			0.50		0.50	
U13	**1.00**	**m3**		**Curing**	**3.50**			**0.10**	**3.50**	**0.10**	**3.50**	
	1.00	h	L1	Average wage1	30.00	0.10		0.10	3.00	0.10	3.00	
	1.00	kg	M8700	Curing materials	0.50				0.50		0.50	
Pricing			**Direct costs**	**Direct cost surcharge**					**SP/TP**	**Deduction**		**Returns**
per qty. Unit			147.00	32.66				0.00	179.66			179.66
			37,485.00	8,328.29				0.01	45,813.30	0.00		45,813.30
0.5.15.	**85.00**	**t**		**Supply & integration of reinforcing steel**						**10.00**	**830.00**	**70,550.00**
U1	**1.00**	**t**		**Supply & integration of reinforcing steel**	**830.00**			**10.00**	**830.00**	**10.00**	**830.00**	
U11	**1.00**	**t**		**Supply of reinforcing steel**	**500.00**				**500.00**		**500.00**	
	1.00	t	M7201	Reinforcing steel “BSt 500”	500.00				500.00		500.00	
U12	**1.00**	**t**		**Integration of reinforcing steel**	**330.00**			**10.00**	**330.00**	**10.00**	**330.00**	
	10.00	h	L1	Average wage 1	30.00			10.00	300.00	10.00	300.00	
	approx. quantity: 10 w1.00		M00	Other materials	30.00				30.00		30.00	
Pricing			**Direct costs**	**Direct cost surcharge**					**UP/TP**	**Deduction**		**Returns**
per qty. unit			830.00	184.41			0.00		1,014.41			1,014.41
			70,550.00	15,674.55			0.30		86,224.85	0.00		86,224.85

Production costs/comprehensive list

Project: 000 Construction of bridge over a brook
Calculation: Bid estimate **Currency: EUR**
Bill of quantities

Item	Quantity	Unit	Calc. key	Description	Costs/ QU	Per. factor	Cost fac.	Hours/ sub-item	Direct costs/sub-item	Hours/ item	Direct costs/item	Total
0.5. Bridge structure												
Main cost types, debit and risk			**Key**	**Description**					**Costs**			
			1	Personnel costs					38,505.00			
			2	Materials					64,302.50			
			5	Equipment costs					5,227.50			
			Total						108,035.00			
			Hours						1,283.50			
			Direct costs	**Direct cost surcharge**					**UP/TP**	**Deduction**		**Returns**
			108,035.00	24,002.84			0.31		132,038.15	0.00		132,038.15
0. Bridge construction												
Main cost types, debit and risk			**Key**	**Description**					**Costs**			
			1	Personnel costs					175,155.50			
			2	Materials					66,848.50			
			3	Auxiliary & operating materials					3,195.60			
			5	Equipment costs					12,610.00			
			7	Subcontractors					7,500.00			
			Total						265,309.10			
			Hours						1,588.50			
			Direct costs	**Direct cost surcharge**					**UP/TP**	**Deduction**		**Returns**
			265,309.10	58,945.46			0.30		324,254.86	0.00		324,254.86
1				**Bridge**								
Main cost types, debit and risk			**Key**	**Description**					**Costs**			
			1	Personnel costs					175,155.50			
			2	Materials					66,848.50			
			3	Auxiliary & operating materials					3,195.60			
			5	Equipment costs					12,610.00			
			7	Subcontractors					7,500.00			
			Total						265,309.10			
			Hours						1,588.50			
			Direct costs	**Direct cost surcharge**					**UP/TP**	**Deduction**		**Returns**
			265,309.10	58,945.46			0.30		324,254.86	0.00		324,254.86

Production costs/comprehensive list

Project: **000 Construction of bridge over a brook**
Calculation: **Bid estimate** **Currency: EUR**
Bill of quantities

Item	Quantity	Unit	Calc. key	Description	Costs/ QU	Per. factor	Cost fac.	Hours/ sub-item	Direct costs/sub-item	Hours/ item	Direct costs/item	Total
				***standard rates apply								
..10.	**(1,00)**	**ea**		**Site provisioning**							**26,520.00**	**26,520.00**
U1	**1.00**			**Site provisioning**	**26,520.00**				**26,520.00**		**26,520.00**	
U1h	**1.00**	**ea**		**Accomodation/off./etc.**	**2,100.00**				**2,100.00**		**2,100.00**	
	200.00	d	G610	Container 6 m	6.50				1,300.00		1,300.00	
	approx. qty: 20 x 10											
	200.00	d	G611	Container 3 m	4.00				800.00		800.00	
	approx. qty: 20 x 10											
U1i	**1.00**	**ea**		**Fueling system (prov.)**	**400.00**				**400.00**		**400.00**	
	160	d	G910	Fueling system	2.50				400.00		400.00	
	approx. qty: 20 x 8											
U1j	**1.00**	**ea**		**Telecommunication**	**500.00**				**500.00**		**500.00**	
	1.00		61	Telecommunication	500.00				500.00		500.00	
U1k	**1.00**	**ea**		**Tower crane (prov.)**	**12,000.00**				**12,000.00**		**12,000.00**	
	8.00	mo	G3009.1	Crane provider (prov.)	1,500.00				12,000.00		12,000.00	
	approx. qty: 8											
U1m	**1.00**	**ea**		**Site operation**	**11,520.00**				**11,520.00**		**11,520.00**	
	240.00	d	G1303	Emergency generator	16.00				3,840.00		3,840.00	
	approx. qty: 8 x 30											
	7,680.00	l	B10	Diesel fuel	1.00				7,680.00		7,680.00	
	approx. qty: 60 x 0.1 x 8 x 20 x 8											
Pricing per qty. unit			**Direct costs** 26,520.00 26.520.00									
2				**Overhead bill of quantities**								
Main cost types, debit and risk			**Key**	**Description**					**Costs**			
			3	Auxiliary & operating materials					7,680.00			
			5	Equipment costs					18,340.00			
			6	Misc.					500.00			
			Total						26,520.00			
			Hours:									
			Direct costs 26,520.00									

Production costs/comprehensive list

Project: **000 Construction of bridge over a brook**
Calculation: **Bid estimate** **Currency: EUR**
Bill of quantities

Item	Quantity	Unit	Calc. key	Description	Costs/ QU	Per. factor	Cost fac.	Hours/ sub-item	Direct costs/sub-item	Hours/ item	Direct costs/item	Total
				Summary of bills of quantities								
1				**Bridge**								
Main cost types, debit and risk			**Key**	**Description**					**Costs**			
			1	Personnel costs					175,155.00			
			2	Materials					66,848.50			
			3	Auxiliary & operating materials					3,195.60			
			5	Equipment costs					12,610.00			
			7	Subcontractors					7,500.00			
			Total						**265,309.10**			
			Hours:						1,588.50			
			Prod. costs	**Prod. costs surcharge**					**TP**	**Deduction**		**Returns**
			265,309.10	58,945.46			0.30		324,254.86	0.00		324,254.86
2				**Overhead bill of quantities**								
Main cost types, debit and risk			**Key**	**Description**					**Costs**			
			3	Auxiliary & operating materials					7,680.00			
			5	Equipment costs					18,340.00			
			6	Misc.					500.00			
			Total						**26,520.00**			
			Hours:									
			Direct costs									
			26,520.00									
Totals of combined bills of quantities												
Main cost types, debit and risk			**Key**	**Description**					**Costs**			
			1	Personnel costs					175,155.00			
			2	Materials					66,848.50			
			3	Auxiliary & operating materials					10,875.60			
			5	Equipment costs					30,950.00			
			6	Misc.					500.00			
			7	Subcontractors					7,500.00			
			Total						**291,829.10**			
			Hours:						1,588.50			
			Direct costs	**Prod. cost surcharge**					**TP**	**Deduction**		**Returns**
			291,829.10	58,945.46			0,3		324,254.86	0.00		324,254.86

Table 2.26 Bid overview of the prestressed concrete bridge

Production costs and bid overview Currency: EUR

Project:	**000 V1 (Bid) Construction of bridge over a brook**	**Closing date:**	
Client:			
Construction branch:		**General overheads:**	**8 %**
		Risk and profit:	**2 %**
		Free surcharges:	**0 %**

Hours		**Costs**	
Hours (normal)	1.589	Production costs (normal)	265.309
+ Hours (std. price)	0	+ Prod. costs (std. price)	0
= Hours (base)	**1.589**	**= Direct costs (base)**	**265.309**
+ Hours (without surcharge)	0	+ Direct costs (without surcharge)	0
= Total hours (normal items)	**1.589**	**= Total direct costs (normal items)**	**265.309**
+ Hours (Site overheads)	0	+ Site overheads	26.520
= Total Hours 1	**1.589**	**= Total direct costs 1**	**291.829**
+ Hours (special items)	0	+ Prod. costs (special items)	0
= Hours (base)	**1.589**	**= Direct costs (offer)**	**291.829**
Hours (special items w/o total)	0	Direct costs (special items w/o total)	0
Allocation		**Bid**	
Preliminary allocation	0	Prod. costs (w/o surcharges & contractor op.)	291.829
+ Site overheads (remainder)	26.520	+ general overhead + risk/reward + free surcharge	32.425
= Site overhead (total)	**26.520**	**= Total 1**	**324.255**
+ General overheads	25.940	+ Prod. costs of all items w/o surcharges	0
+ Risk and profit	6.485	+ Contractor op. (w/o surcharges)	0
+ Free surcharges	0		
= Calculated allocation	**58.945**	**= Total 2**	**324.255**
+ Claims coverage (surcharge items)	0	+ Deficits	0
+ Other deficits	0		
+ Manual surcharge	0		
= Actual allocation	**58.945**	**= Total 3**	**324.255**
		+ Total price (special items)	0
		= Total 4	**324.255**
		+ Deduction and rounding	0
		= Bid sum acc. bill of quanitites	**324.255**

Average wage:	30.00
Average direct cost surcharge:	6.67
Average calculated wage:	36.67

Production costs and bid overview Currency: EUR

Project:	**000 V1 (Bid) Construction of bridge over a brook**	**Closing date:**	
Client:			
Area of construction:		**General overheads:**	**8.00 %**
		Risk-and profit:	**2.00 %**
		Free surcharge:	**0.00 %**

Cost types	Description	Normal item	Special items and total	Site overhead costs	Total	% Construction costs	% Bid sum
	Hours	**1,589**	**0**	**0**	**1,589**		
1	Personnel costs	175,155	0	0	175,155	60.02	54.02
1.0	Wage costs	0	0	0	0	0.00	0.00
1.1	Foremen wage costs	0	0	0	0	0.00	0.00
1.2	Employee wage costs	0	0	0	0	0.00	0.00
2	Material	66,849	0	0	66,849	22.91	20.62
2.0	Concrete	0	0	0	0	0.00	0.00
2.1	Steel	0	0	0	0	0.00	0.00
2.2	Assembly parts	0	0	0	0	0.00	0.00
2.3	Prefabricated concrete parts	0	0	0	0	0.00	0.00
2.4	Masonry materials	0	0	0	0	0.00	0.00
2.5	Earth-moving and road construction materials	0	0	0	0	0.00	0.00
2.6	Expansion and MEP materials	0	0	0	0	0.00	0.00
3	Auxiliary and operating material costs	3,196	0	7,680	10,876	3.73	3.35
3.0	Formwork and scaffolding materials	0	0	0	0	0.00	0.00
3.1	Sectional steel (support structures)	0	0	0	0	0.00	0.00
3.2	Lining materials	0	0	0	0	0.00	0.00
3.3	Operating materials, water, electricity	0	0	0	0	0.00	0.00
3.4	Explosive materials	0	0	0	0	0.00	0.00
3.5	Auxiliary and misc. materials	0	0	0	0	0.00	0.00
4	General construction, operating, and business expenses	0	0	0	0	0.00	0.00
4.0	Site facilities and administration	0	0	0	0	0.00	0.00
4.1	Project costs	0	0	0	0	0.00	0.00

5	Equipment costs	12,610	0	18,340	30,950	10.61	9.54
5.0	Equipment rent and maintenance costs	0	0	0	0	0.00	0.00
5.1	Additional equipment costs	0	0	0	0	0.00	0.00
6	Other	0	0	500	500	0.17	0.15
6.0	Third-party services: Subterranean engineering, roads and tunnels	0	0	0	0	0.00	0.00
6.1	Third-party services: Structural work	0	0	0	0	0.00	0.00
6.2	Third-party services: Expansion	0	0	0	0	0.00	0.00
6.3	Third-party services: MEP	0	0	0	0	0.00	0.00
6.4	Other	0	0	0	0	0.00	0.00
6.5	Architecture and engineering services	0	0	0	0	0.00	0.00
8	Other business expenses	0	0	0	0	0.00	0.00
8.0	Interest rate	0	0	0	0	0.00	0.00
8.2	Provisioning	0	0	0	0	0.00	0.00
8.4	Office and business costs, EDP, travel, catering	0	0	0	0	0.00	0.00
8.5	Insurance, lawyer, consultation costs and fees	0	0	0	0	0.00	0.00
8.6	Other taxes	0	0	0	0	0.00	0.00
8.7	Other costs	0	0	0	0	0.00	0.00
8.8	Market fluctuation losses/gains	0	0	0	0	0.00	0.00
8.9	Commissions, fees	0	0	0	0	0.00	0.00
7	Subcontractors	7,500	0	0	7,500	2.57	2.31
Total	**Production costs**	**265,310**	**0**	**26,520**	**291,830**	**100.00**	**90.00**
	General overhead costs	23,583	0	2,357	25,940	8.89	8.00
	Risk and reward	5,896	0	589	6,485	2.22	2.00
	Free surcharges	0	0	0	0	0.00	0.00
	Surcharge for special items		0		0	0.00	0.00
	Preliminary allocations	0		0			
	Surcharge on preliminary allocations	0		0			
Total	**Bid sum 1**	**294,789**	**0**	**29,466**	**324,255**	**111.11**	**100.00**
	Contractor operations	**0**	**0**	**0**	**0**	0.00	0.00
	Production costs of partial service	**0**	**0**	**0**	**0**	0.00	0.00

Total	**Calculated bid sum**	**294,789**	**0**	**29,466**	**324,255**	**111.11**	**100.00**
	Site overhead costs and production cost surcharge on site overhead costs	29,466		-29,466			
	Manual surcharge	0	0		0	0.00	0.00
	Claims coverage	0	0		0	0.00	0.00
Total	**Bid sum according to calculation**	**324,255**	**0**		**324,255**	**111.11**	**100.00**
	Discount and rounding				0		0.00
	Bid sum according to bill of quantities				**324,255**		**100.00**
	VAT				61,608		
Total	**Gross bid sum**				**385,863**		

Calculated wages Currency: EUR

Project:	**000 V1 (Bid) Construction of bridge over a brook**	**Closing date:**	
Client:		**Section**	**Other**
Construction branch:		**Average general overheads:**	**8.00 %**
		Average risk and profit:	**2.00 %**
		Average free surcharge:	**0.00 %**

Cost types	**Description**	**Average wage**	**Production cost surcharge**	**Calculated wage**	**Hours**	**Hours x Av. Wage**	**Hours x column 4**	**Hours × Calc. Wage**
Wage1	Aver. Wage 1	30.00	6.67	36.67	1,588.50	47,655.00	10,587.82	58,242.82
Sum					**1,588.50**	**47,655.00**	**10,587.82**	**58,242.82**
Average		**30.00**	**6.67**	**36.67**				

Surcharges and allocation factors per section Currency: EUR

Project:	**000 V1 (Bid) Construction of bridge over a brook**	**Closing date:**	
Client:		**Section**	**Other**
Construction branch:		**General overheads:**	**8.00 %**
		Risk and profit:	**2.00 %**
		Free surcharge:	**0.00 %**

Cost types	Description	General overheads	Risk surcharge	Free surcharge	Final surcharge	Total factor	Ges. Fac. B.Pos
1	Personnel costs	8.00	2.00	0.00	11.11	22.22	22.22
2	Material	8.00	2.00	0.00	11.11	22.22	22.22
3	Costs for auxiliary and operating materials	8.00	2.00	0.00	11.11	22.22	22.22
4	General construction costs, operating costs, and business expenses	8.00	2.00	0.00	11.11	22.22	22.22
5	Equipment costs	8.00	2.00	0.00	11.11	22.22	22.22
6	Other costs	8.00	2.00	0.00	11.11	22.22	22.22
7	Subcontractors	8.00	2.00	0.00	11.11	22.22	22.22

Table 2.27 Completed bill of quantities of the prestressed concrete bridge

Item	Description	Qty.	QU	Unit price (EUR/QU)	Total price (EUR)
	Bridge construction				
1	**Construction site facilities**				
1.1	**Establishment and provisioning of construction site facilities** Transport and provision equipment, tools, and other operating resources required for the contractual realization of construction services to construction site, and assemble and make equipment ready for construction provided the employment of equipment is not billed separately. Create facilities including construction offices, accommodations, workshops, storage units and so on; and, if required, deliver, assemble, and install related units and elements. Install electricity, water, telecommunication lines, and sanitary facilities to required extent. If needed, create storage space, delivery roads, and other infrastructure. Perform top-soil work, as required, including removal of local plant growth. Moreover, create surface areas for construction work if those provided by the client do not suffice. Provision, maintenance,	1	ea	189,040.03	189,040.03

	and operating costs of equipment, facilities, and installations including rents, fees, and so forth are not billed using standard rates but rather using the unit price of the respective partial service. Provided that separate items for services involving the establishment of the construction site are not included in the bill of quantities, the standard rate applies to all services across all sections in the bill of quantities. Create vehicle access road to the construction site, which is billed separately.				
1.2	**Clearing of construction site** Clear all equipment, facilities, installations, and so forth from construction site. Restore used surface areas and roads according to their initial state. If the bill of quantities does not list separate items for the clearing of the construction site, the standard rate applies to all services across all sections of the bill of quantities.	1	ea	3,176.68	3,176.68
	Construction site facilities total				**192,216.71**
2	**Bridge structure**				
2.1	**Production of reinforced concrete including formwork** Produce reinforced concrete and formwork according to documents provided by the client. Provision and remove formwork. Reinforcing and scaffolding are not billed separately. Components = abutment + abutment walls, substructure inspection chamber. Utilized material = reinforced concrete. Compressive strength class C30/37. Exposure classes XF2, XC4, and XD1. Additional requirements: W/c ratio ≤ 0.5. Visible surface area of formwork = timber boards planed on one side of identical cross-section with profiled sides (tongue and groove or similar). Formwork is assembled horizontally. Deburr surface area mechanically.	255.00	m^3	179.66	45,813.30
2.2	**Transport and integration of reinforced concrete** Integrate reinforced concrete in accordance with structural and construction requirements. Components = foundation, abutment with abutment wall, central pillar, bearing pedestal, chamber wall, revision chamber. Type of steel = BSt 500 S.	85.00	t	1,014.41	86,224.85
	Bridge structure total				**132,038.15**
	Bridge construction total				**324,254.86**

Summary

Construction site facilities	192,216.71 EUR
Bridge structure	132,038.15 EUR
Bridge construction total	324,254.86 EUR
Bid sum (net)	324,254.86 EUR
VAT (19 %)	61,608.42 EUR
Bid sum (gross)	**385,863.28 EUR**

2.5 Estimating in tunnel construction

2.5.1 Introduction

In a first basic categorization, tunnel construction may be divided into open and closed construction methods. Open construction means the tunnel construction site is created in an open construction pit, which is refilled after project realization. This method is usually employed for tunnel structures close to the surface. In the latter case, the tunnel is excavated either using a tunnel boring machine (e. g. cutting shield or open tunnel boring machine) or using mining techniques (conventional excavation using means of, e. g., boring or explosives).[58] A special case in tunnel construction is the so-called floating assembly method for submerged construction, in which one or more caissons are submerged and then connected to one another so as to keep the whole construction watertight.[59]

2.5.2 Example – Cutting shield boring

2.5.2.1 Work specifications

The following chapter addresses estimating processes and involved costs for boring two tunnel tubes (east and west tube) of a tunnel structure, running in north-south direction, as underpass to a river. Planning involves employment of two tunnel boring machines (TBMs) for this construction. In this example, both tunnels are created in a depth of 60 m below ground level with cutting shield and will have a final length of 6.6 km. The excavation chamber is supported with bentonite.

Using the cutting shield construction method, a steel cylinder, the internal diameter of which is slightly larger than the outer diameter of the tunnel wall, is pushed into the soil with hydraulic presses. Covered by the cutting shield, the forward part of the equipment excavates the soil while the final ring-shaped tunnel is created in the wake of the machine. The annular clearance between outer tunnel wall and surrounding mountainous soil emerging during the boring process is grouted (i. e. sealed) immediately.

Prefabricated tunnel segments made of reinforced concrete are used for this process in this specific example. Hydraulic presses employed during the boring process are

58) Cf. closed construction method with tunnel boring machines, e. g. in Girmscheid (2008), pp. 381–436, and cf. boring methods using conventional means or explosives in ibidem (2008), pp. 71–132.

59) Cf. floating assembly method and caissons respectively in Lingenfelser (2001), p. 233 ff.

supported with thrust pads in the finalized parts of the tunnel. The cutting shield is controlled through pressure redistribution, which allows it to bend the tunnel. The minimum radius of the cutting shield is given with 50 m, whereas the shield's outer diameter defines the boring process and excavated volumes. Boring with a cutting shield is mostly used for excavating in loose rock and cohesive soils.

In this case, the excavated rock face is supported by slurry under pressure, which completely fills the tunnel, sealed off tightly against the boring area, up to the roof and exerts pressure onto the rock face. Either cutting equipment or star-shaped cutting wheels are used for excavation. During the boring process, slurry is mixed with extracted soil. The mixture is transported above ground and separated with the slurry being pumped back into the excavation area. Here, pressure of the supporting slurry needs to equal earth pressure and stay constant. Pressure equalization may be attained through controlling the flow of slurry from and to the excavation area or through assembly of an air compression chamber where controlled air pressure is exerted at level of the supporting slurry. The basic structure of a TBM is shown in Figure 2.13.

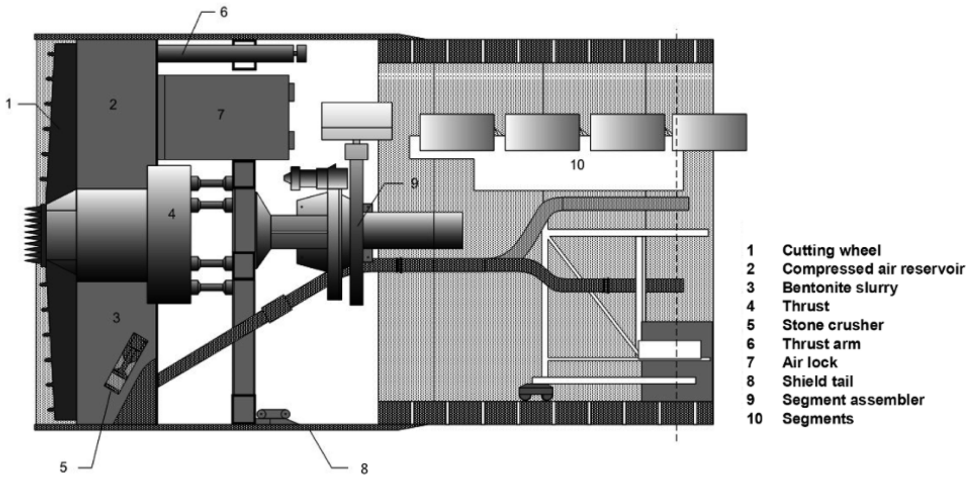

Figure 2.13 Schematic section of a tunnel boring machine

In case of emerging obstacles or cutting wheel maintenance requirements, the supporting slurry is displaced with compressed air. Operations in the excavation area may then proceed under compressed air. Staff is transported to and from the excavation area via airlock. In ground water areas, the tail end of the cutting shield has to be made watertight to prevent the intrusion of ground water.

Contractual conditions
Contractual agreements in tunnel construction for the provision of TBM by the manufacturer usually include a number of items with respect to performance and process times as well as TBM availability, which guarantee a certain boring rate. This boring rate is part of the most substantial bases for the calculation of prices and costs by the contractor for creating both tunnel tubes.

In general, guarantees involve times and rates of processes crucial to the boring of the tunnel tube:

- Boring with cutting wheel
- Assembly time of prefabricated tunnel segments
- Extending supply and disposal pipes
- Availability of the TBM for boring processes
- Average boring performance

2.5.2.2 Boring rate and progress rate

Boring rate

Boring rate defines the actual boring process, i.e. the process during which the TBM actually progresses through rock and soil. With respect to geological conditions, the TBM manufacturer guarantees varying boring speeds. Table 2.28 shows guaranteed average boring speeds in mm/min relative to geological conditions and layers as well as hydraulic pressures present in the geological sections that have to be bored through. Additionally, the table includes boring rates in m/h and m/WD.

Table 2.28 Development of boring rate in tunnel construction

Pos.	Geological layers	Type of operation	Boring location		Bor-ing length	Contractual cutting speed per geological layer		Boring performance	
			Start	End				Operation time T_T	Boring performance
							A		B
			[m]	[m]	[m]	[mm/min]	[m/h]	[h/WD]	[m/WD1)]
1	Sand (Z1)	Test Drive	0	230	230	40	2.4		
2.1	Sand/Clay (Z1/BK1)		230	300	70	30	1.8		
2.2	Sand/Clay (Z1/BK1)	Regular operation	300	350	50	30	1.8	24	43.2
3	Sand/Clay (Z1/BK1)		350	420	70	30	1.8	24	43.2
4	Clay (BK1/2)		420	570	150	20	1.2	24	28.8
5	Clay/Sand (BK2/GZ2)		570	850	280	30	1.8	24	43.2
6	Sand (GZ2)		850	1,430	580	35	2.1	24	50.4
7	Clay/Sand (BK2/GZ2)		1,430	1,980	550	30	1.8	24	43.2
8	Clay (BK1/2)		1,980	3,980	2,000	25	1.5	24	36.0
9	Sand/Clay (GZ1/BK1)		3,980	5,180	1,200	30	1.8	24	43.2
10	Sand (GZ1/Z1)		5,180	6,260	1,080	40	2.4	24	57.6
11	Sand (GZ1/Z1)		6,260	6,600	340	40	2.4	24	57.6
					6,600	31.2	1.9		44.9

1) WD = Workday = 24 h

A x 24 h/WD = **B**

Ring construction
In order to expedite the boring process as much as possible, it is important to keep the period needed to completely assemble a ring of eight prefabricated reinforced-concrete tunnel segments (7 + 1 ring construction time) and reattach hydraulic presses as short a time as possible, which is pivotal to the cumulative boring rate.

Provided that qualified staff is on site, the TBM manufacturer guarantees that construction time per ring does not exceed 30 minutes.

The same applies for the extension of supply pipes. However, since extensions may be realized parallel to ring construction, some of the time needed for the effort is "dwarfed" by the ring construction time. As a result, the greater amount of time spent with respect to the cumulative boring rate is reflected in the calculation process.

Moreover, the TBM manufacturer guarantees that pipes for „slurry cycle, water supply, emergency drainage and emergency air supply" can be extended over a length of 12 m within 45 min.

The calculation process for the required boring rate or, conversely, the required amount of time it takes to bore a certain distance, consists of the partial processes above. The process also involves further amounts of added-on or lost time resulting in an average rate, which stays consistent over longer periods of time. This state of consistency usually only arises after the TBM and its tail are inside the tunnel tube over the full length of the machine, and an initial, so-called "test drive" has been completed.

The TBM manufacturer guarantees that after completion of the initial test drive over the first 300 m, an average boring rate of 15 m in 24 h over a total period of six days will have been achieved. The manufacturer has to provide proof of this average in an agreed section between 300 and 600 m.

2.5.2.3 Availability

In order to plan construction of a tunnel according to schedule and within the deadline, the average continuous rate is important. Making an estimate regarding the average continuous rate in conjunction with the above mentioned performance restraints is only possible under provision of an unimpeded operation of the TBM.

"Availability" in this case is determined as the ratio of time within three shifts of eight hours per workday (WD), during which operations are supposed to run with the boring personnel, and the time during which the TBM is actually available for boring, ring construction, and pipe extension operations in an unimpeded manner.

For every TBM, the manufacturer guarantees that after 300 m of test driving, there will be an operative availability of at least 85 % of the construction time for boring and assembly of tunnel ring segments, respectively. Construction time means the period of time during which the staff of the contractor is available for construction purposes (a three shift system from Monday morning at 6:00 a.m. to Sunday morning at 6:00 a.m. is assumed). This potential working time might be reduced by:

- Downtime caused by the tunnel contractor
- Delays due to damages done to equipment involved in the boring process, caused by tunnel contractor
- Planned maintenance
- Downtime caused by replacement of excavation or cutting devices

Calculation of availability is performed according to the following formula.

F availability

T_T actual working time

T_A downtimes due to TBM maintenance etc.

T_1 operational downtimes

T_2 damages

T_3 maintenance

T_4 device replacement

$$f\left[\%\right]=\frac{T_T - (T_1 + T_2 + T_3 + T_4) - T_A}{T_T - (T_1 + T_2 + T_3 + T_4)} \times 100$$

Availability is measured from the moment the first permanent ring has been assembled to the moment the TBM arrives at level of the created wall of the reception shaft. Availability is calculated on a monthly basis. Procedures for registration, definition, evaluation and reporting are included in the non-optional manual provided by the manufacturer upon receiving the TBM. The test drive is included in the calculation of availability. Monthly recalculations are sensible in this regard, rather than on the basis of the whole construction period of two years and three months, as possible later adjustments of the TBM by the manufacturer have to be considered in the sense that "catching up later" is prone to quickly reach technical limitations.

The boring progress and tunnel construction directly influence costs regarding time and performance required during the tunneling project. It is hence imperative to differentiate and compare guaranteed, calculated, and actually achieved progress speeds.

2.5.2.4 Classification of work-shift times of boring personnel

Eight-hour-shift times are usually classified in shift protocols and weekly reports as follows:

1. Boring time
2. Ring construction time
3. Downtime
4. Time working under compressed-air conditions
   (1) Boring time is the part of the construction schedule, during which the TBM is driven forward along the conceived tunnel path via hydraulic presses.

(2) During ring construction time, the TBM is at rest, which is inherent to the tunnel construction process as hydraulic presses are retracted in this stage. While the TBM is down, a ring consisting of 7 + 1 prefabricated reinforced-concrete tunnel segments is assembled. Furthermore, the extension of supply pipes after 12.0 m of boring progress falls into this category. The resulting normalized cycle is shown in the following figure, which depicts six rings for every 12 m of boring progress and a target cycle time of 9.55 h and target boring rate of 1.26 m/h.
(3) Downtime denotes any irregular suspension of operations and, in part, contingent downtimes, which commonly emerge during boring processes with cutting shield. They occur randomly with incalculable suspension times. Later chapters show a categorization of downtimes according to their sources.
(4) Working under compressed-air conditions means periods of time, also viewed as downtimes, during which maintenance work is performed in close proximity behind the cutting wheel requiring intervention with compressed air inside the compression chamber. Such periods may occur due to machine faults as well as geological or mechanical reasons.

Classification of boring periods
In order to draw a comparison among forward-progress speeds, the boring rate is calculated using a number of indicators for progress speeds and times of sub-processes. The performance rate is given as boring progress per workday [m/WD]. Construction, as part of the cumulative construction time available for actual tunnel construction and boring, is performed during six workdays per week in three shifts, i. e. tunnel construction and boring take place 24 h a day. Chart 2–14, “Structural diagram of boring processes”, gives an overview of the various boring periods.

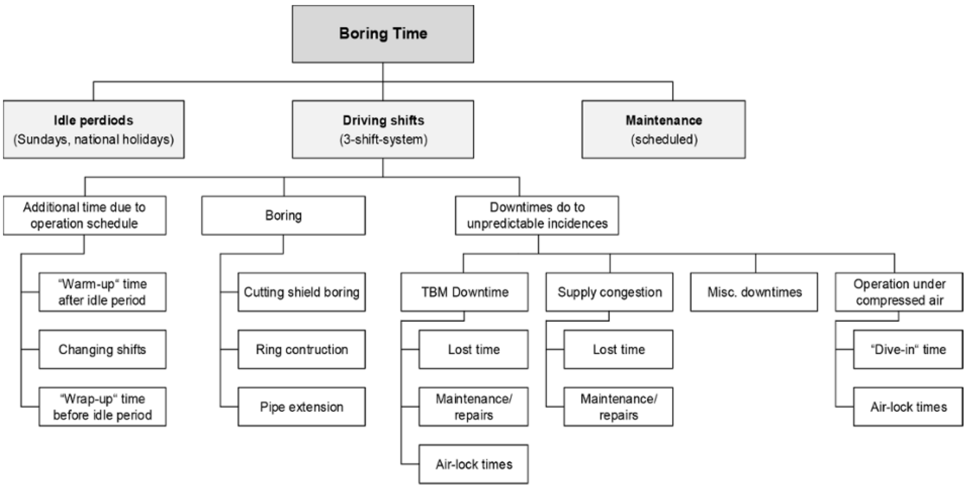

Figure 2.14 Structural diagram of boring processes

2.5.2.5 Standard boring schedule

Rough draft of a schedule for tunnel construction
Figure 2.15 shows the planned scheduling prior to assembly of the TBM into the tunnel entrance. After assembly, the actual boring times for tunnel tube west and tunnel tube east are estimated with 575 and 546 workdays, respectively.

ID	Task Name	Duration
1	**Tunnel Construction**	**806d**
2	Entry/start structure south	120d
3	Exit structure north	120d
4	**Boring West**	**642d**
5	Entry of TBM	4d
6	Test drive	57d
7	Boring	575d
8	Exit	19d
9	**Boring East**	**687d**
10	Entry of TBM	4d
11	Test drive	57d
12	Boring	546d
13	Exit	19d

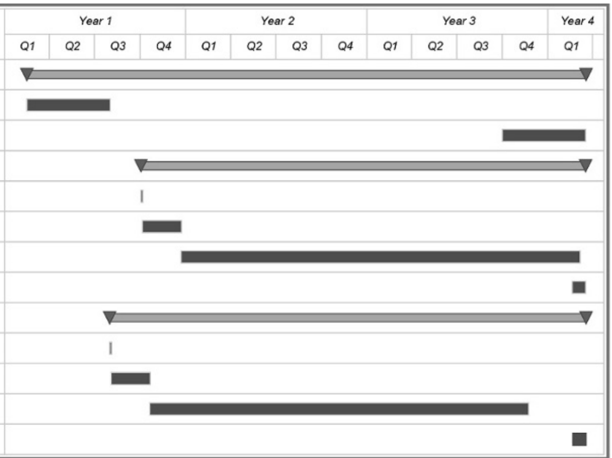

Figure 2.15 Example of a schedule for tunnel construction

Standard schedule for boring processes
Time periods inherent in boring processes and essential components of standard boring procedures are as follows:

– Forward-progress time (i. e. excavation)
– Ring construction time
– Supply pipe extension
– Boring device / tool replacement

The sum of these processes result in a detailed standard schedule as shown by the figure 2.16, which denotes the maximum boring rate within the mechanical limitations of the TBM.

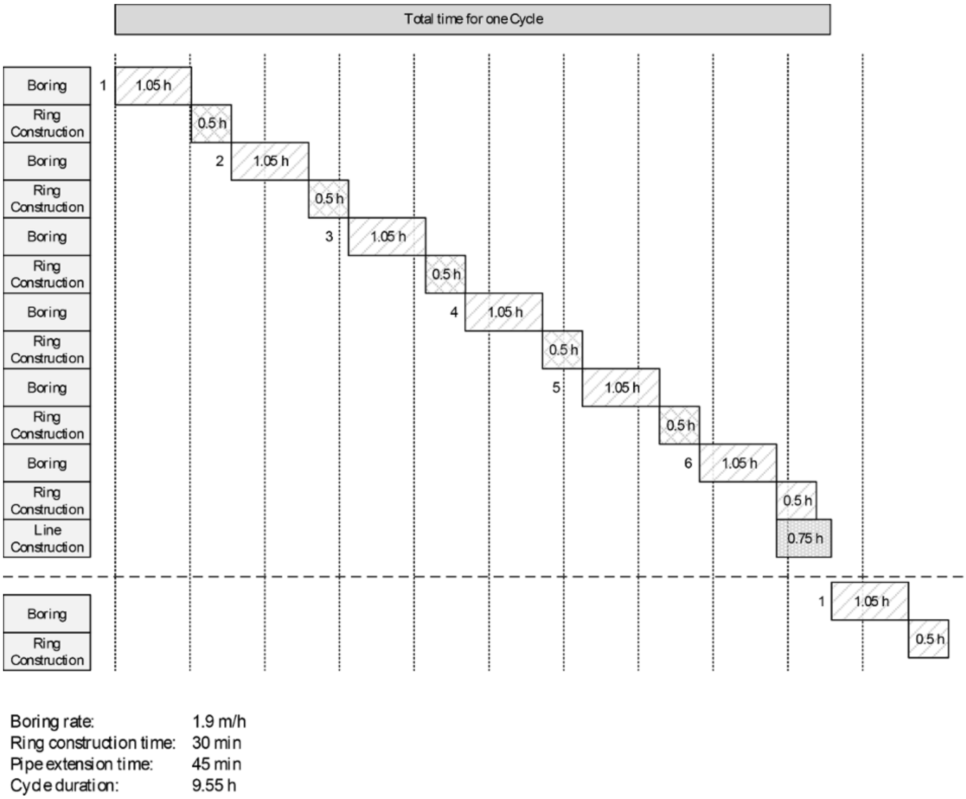

Figure 2.16 Standard schedule: Boring process with ring construction and supply pipe extension

Levels of performance rates for calculated continuous performance

In order to identify the expected boring performance, various performance rates have to be taken into consideration, which clarify that the target performance is a continuous performance varying between certain performance limits, as average shift or workday performance over long periods of time. Following are variations of levels of performance of boring rates where BR = boring rate:

BR1 Maximum boring rate in present geological conditions according to cutting wheel performance

The maximum boring rate found in Table 2.28 (Development of boring rate in tunnel construction) of 2.4 m/h (57.60 m/WD) is the highest average boring speed with respect to existing geological layers. This maximum rate only applies to unimpeded boring progress between ring construction times and cannot, from a mechanical point of view, be exceeded.

BR2 Average boring speed over complete tunnel distance

The average boring speed of 1.9 m/h or 45.60 m/WD means a weighted average of boring speeds in existing geological layers.

BR3 Maximum boring rate according to mechanical limits and regular schedule

The average boring rate of 30.16 m/WD applies to regular scheduling, i.e. including ring construction and pipe extension times, during which the TBM stands immobile, together with the guaranteed process times.

BR4 Estimated boring rate after application of availability guaranty

Different from the above performance levels where unimpeded machine operation is assumed, BR4 includes a factor of 85 % operating time into the calculation resulting in a boring rate of 17.65 m/WD.

BR5 Guaranteed average boring rate

The guaranteed average boring rate of 15 m per 24 h denotes a rate, which is achieved on average even at the limit of guaranteed minimum availability.

BR6 Calculated boring rate

Calculation of the available construction time for the tunnel yields a core time for actual boring rate after test drive, which is the basis for cost estimates. In reality, impediments which influence boring rate and project operations have to be taken into consideration, here, in contrast to unimpeded (hypothetical) activities.

BR7 Required boring rate

The required boring rate is calculated according to the cumulative amount of available workdays, as per schedule, over the tunnel distance of 6,600 m to the target construction site. The calculated boring rate, in contrast to required boring rate, should include certain reserves or buffers for unexpected delays.

For the boring process in direction east, the rate is:

$$\frac{6{,}600\ \text{m}}{687\ \text{WD}} = 9.61\frac{\text{m}}{\text{WD}}$$

And for the process in direction west, the rate is:

$$\frac{6{,}600\ \text{m}}{642\ \text{WD}} = 10.28\frac{\text{m}}{\text{WD}}$$

Figure 2.17 gives an overview of the performance levels above.

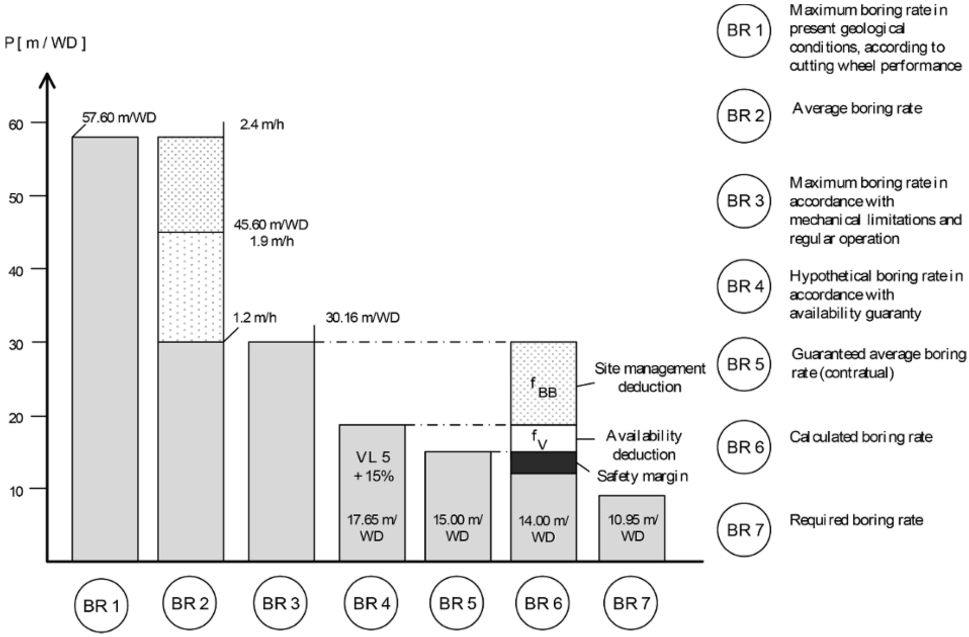

Figure 2.17 Comparison of boring rates / performance levels

2.5.2.6 Boring rates and downtimes

Target boring rate and schedule

Target performance in accordance with the outlined levels of performance is calculated as follows: Performance level BR3, which denotes the maximum boring rate acquired via the mandatory construction cycle of boring – ring construction – pipe extension, is subject to operational and logistical deductions while the TBM is inactive. Accordingly, during periods free of downtimes, the TBM should, in theory, achieve the boring rate under performance level BR3. However, a deduction of 15 % towards the target time for boring operations has to be included as contractually permissible TBM downtime. Furthermore, 1.0 m / WD are subtracted as a safety margin from the guaranteed average boring rate, which can be continuously maintained, resulting in the calculated boring rate. Together with the calculated boring rate, the demand for prefabricated tunnel ring segments is determined as a target value for the manufacturing of these elements.

The required time for boring through present geological layers is identified according to the various boring speeds established for different soil conditions and according to Table 2.29.

Table 2.29 Development of boring rates – Target, TBM 1 (east) and TBM 2 (west)

Stage	Geological layers	Type of operation	Boring location		Boring length/shift	Contractual cutting speed per geological layer		Maximal boring performance BP3			Calculated boring performance per geological layer BPcalc			Calculated construction time
			Start	End				Operating time	BP3		Operating time	BPcalc		
			[m]	[m]	[m]	[mm/min]	[m/h]	[min/WD]	[m/h]	[m/WD]	[min/WD]	[m/h]	[m/WD]	[WD]
1	Sand (Z1)	Test Drive	0	230	230	40	2.4							
2.1	Sand/Clay (Z1/BK1)		230	300	70	30	1.8							
2.2	Sand/Clay (Z1/BK1)	Regular operation	300	350	50	30	1.8	910	0.7	17.5	750	0.6	14.4	43.2
3	Sand/Clay (Z1/BK1)		350	420	70	30	1.8	910	0.7	17.5	750	0.6	14.4	43.2
4	Clay (BK1/2)		420	570	150	20	1.2	800	0.5	11.6	660	0.4	9.6	28.8
5	Clay/Sand (BK2/GZ2)		570	850	280	30	1.8	910	0.7	17.5	750	0.6	14.4	43.2
6	Sand (GZ2)		850	1,430	580	35	2.1	960	0.8	20.3	790	0.7	16.7	50.4
7	Clay/Sand (BK2/GZ2)		1,430	1,980	550	30	1.8	910	0.7	17.5	750	0.6	14.4	43.2
8	Clay (BK1/2)		1,980	3,980	2,000	25	1.5	850	0.6	14.5	700	0.5	11.9	36.0
9	Sand/Clay (GZ1/BK1)		3,980	5,180	1,200	30	1.8	910	0,7	17.5	750	0.6	14.4	43.2
10	Sand (GZ1/Z1)		5,180	6,260	1,080	40	2.4	1,020	1.0	23.3	840	0.8	19.2	57.6
11	Sand (GZ1/Z1)		6,260	6,600	340	40	2.4	1,020	1.0	23.3	840	0.8	19.2	57.6
					6,600	31.2	1.9	Average = 18.0 m/WD			Average = 15.00 m/WD			Total WD 442.0

[1] WD = Workday = 24 h

Classification of downtime

Separation

Separation means isolation of bentonite slurry, the used delivery material, from excavated materials. Hence, the separation process does not only intersect with the delivery cycle but is a direct part of it. Separation begins at the discharge pipe of the delivery pressure pipe system where the mixture of excavated materials and slurry is separated via coarse sieve in the first stage of separation. Separation ends at the pump suction nozzle of the delivery pump, which reintegrates recycled bentonite into the delivery cycle.

Delivery cycle

The cycle of bentonite delivery between separating facility and compression chamber consists of a supply and a removal stream and begins at the pump suction nozzle, the access point to the separating facility, as was described in section 2.1. From this intersection, unpolluted bentonite is delivered into the compression chamber behind the cutting wheel. There, the slurry is combined with the material excavated by the cutting wheel, removed, and transported back to the separating facility as polluted mixture.

The delivery system consists of feed, booster pumps, pumps which mitigate pressure losses, and a delivery pipe system including bypass pipes and slide gate valves.

The access point to the TBM part of the delivery system is located separately from the pipe extension facilities. Hence, this continually extended part of the delivery cycle is independent from the TBM. This applies in the same manner to any other delivery or supply pipe systems.

Supply

Supply, in this case, consists partly of facilities that are part of the TBM as well as separate, stationary facilities operated by subcontractors. Specifically, they include the following:

- Pipes for water supply, cooling water, ventilation
- Power supply lines, telecommunication lines
- Rail line construction and operation
- Delivery of prefabricated tunnel segments
- Annular clearance grouting materials

Warm-up/cool-down time

Warm-up and cool-down both denote operational states during the boring process.

Miscellanea

Some sources for downtime are categorized as miscellanea and include both other facilities or facility elements as well as processes inherent to construction with cutting shield. However, it has to be noted that listed impediments are independent from the TBM and are hence not further classified as TBM downtimes.

Tunnel expansion

Tunnel expansion processes are realized in the wake of the TBM, so to speak, in the completed tunnel tube and have little influence on the progress of the TBM or as source for downtimes.

2.5.2.7 Determination of costs and pricing

Cost-type structure of total costs
Construction of this tunnel and other constructions regarding this thoroughfare was calculated as a design-build contract at a global fixed price. With exception of the following cost elements:

- Calculated profit
- Total entrepreneurial risk and administrative costs
- Management costs of the business group
- General business costs and coverage contributions by the business partners

All contract-dependent costs can be calculated as direct costs.

Total costs
Table 2.30 shows the total calculated costs for the construction project.

Table 2.30 Preliminary calculation – Tunnel construction

Description	Calculated Amount
Pre-fabrication of tunnel segments	75,216,965.53 €
Manufacturing, assembly, disassembly of TBMs	44,999,039.47 €
Time-dependent costs of construction site south	63,303,109.34 €
Pre-fabrication of cable tunnel elements	7,690,209.15 €
Separating facility	16,079,801.15 €
Machinery and maintenance	10,649,448.99 €
Manufacturing, assembly, disassembly of logistics system	6,669,494.67 €
Tunnel expansion	82,344,978.75 €
Planning, preparations, drafting, consultations	15,798,068.83 €
Tunnel cross-cuts	25,312,435.79 €
Total	**348,063,551.67 €**

The following paragraphs give a more detailed calculation process analysis for some items in the table.

Wage costs
Work shift costs

For the example project here assumes the use of cutting shield boring, tunnel construction with prefabricated tunnel segments and hydraulic delivery of excavated materials, as well as a construction operation in three shifts. Wage costs for the maintenance crew fall into the category of maintenance for equipment. Staff in monitoring positions, i. e. non-productive foremen, and costs for construction management personnel, including premium payments, are summarized as overheads.

The average wage, as the arithmetic average of union wages according to the various professions, including any ancillary wage costs, is used in order to determine wage costs.

Ancillary wage costs, usually a percentage of the union wage, are the sum of employment insurance (health, nursing care, retirement, unemployment benefits), additional wage payments (holiday pay, transitional allowance), and operational social costs. For the example, surcharge for social costs amounts to 82 % on union hourly wages. Moreover, a 10 % surcharge on union hourly wages is assumed for traveling and subsistence costs.

Table 2.31 Calculation of average wage in tunnel construction

Number of workers	Job title	Wage group	Task	Comments
1	Machine operator	WG 4	Cutting shield driver	Machine operation, review of work during downtime
2	Specialist engineer	WG 4	Ring construction engineer	Assembly of prefabricated ring segments, operation of erecting machinery, annual clearance grouting
1	Construction worker	WG 2	Auxiliary worker	Installation of delivery pipes
1	Machine operator	WG 4	Train driver	Transport of personnel and materials in tunnel tube
1	Skilled construction worker	WG 2a	Mechanic	Maintenance/repairs of shield machine and other equipment
1	Skilled construction worker	WG 2a	Electrician	Maintenance/repairs of electric equipment of TBM
7	Sum of TBM personnel per shift			
1	Skilled construction worker	WG 2a	Maintenance	Separation facility
1	Skilled construction worker	WG 2a	Maintenance	Manufacturing and delivery of grouting materials

1	Machine operator	WG 4	Crane operator	Transport of materials and equipment
1	Construction worker	WG 2	Assemblyman	Preparation of assembly of prefabricated tunnel segments
1	Machine operator	WG 4	Wheel loader	Above-ground horizontal transportation
5	Sum of above-ground personnel			

Number of workers	Wage group	Total union hourly wage (EUR)	Fixed amount (EUR)	Total wage (EUR)
6	WG 4	15.48	13.00	93.34
2	WG 2	12.85	12.00	25.84
4	WG 2a	13.80	12.00	55.49
12	Number of employees (E)	Base average wage		14.56

	Base average wage			14.56 €/h
+	Impediments for tunnel construction		0.70 €/h (assumed)	
	0.70 €/h x 7 employees below ground/12 employees total			0.41 €/h
+	Night work charge	20 %	on 1/3 of work hours	0.97 €/h
+	Productivity bonus	10 %	of 14.56 €/h	1.46 €/h
=	Subtotal			17.40 €/h
+	Social costs	82 %	of 17.40 €/h	14.26 €/h
=	Subtotal			31.66 €/h
+	Ancillary wage costs	2.7 %	of 14.56 €/h	0.85 €/h
=	Average wage			**32.51 €/h**

Using the three-shift-system, wage costs per work day are as follows:

Daily wage costs = 32.51 €/h x 24 h/shift x 12 employees = 9,362.88 €/WD

Additional costs for interventions with compressed air

In addition to per-shift labor costs, so-called interventions with compressed air (CA interventions) accrue further costs. CA interventions are required for the removal of obstacles behind the cutting shield or to replace cutting devices of the cutting wheel, which require a team of workers to enter the excavation chamber while air pressure is sustained by compressed air. The pressure conditions in the excavation chamber against water and earth amount to about 2.5 bar, equal to the hydraulic pressure present at a depth of 25 m. Usually, a team of two or three workers descends into the excavation chamber for maintenance procedures or similar tasks. The staff is required to undergo medical testing in order to verify their ability to work under such pressure conditions. To ensure the safety of staff, there are certain maximum values regarding the amount of time staff is allowed to stay in the excavation chamber and time required inside the decompression chamber. The values are quoted in respective regulations for working under compressed air and different pressure conditions. For the example case (pressure condition of 2.5 bar), the maximum amount of time spent in the excavation chamber is 210 min (3.5 h) in conjunction with a decompression chamber transfer time (1.0 bar and up with oxygen) of 107 min.

Generally speaking, it can be assumed that no more than two workers per shift are fit to work under the pressure conditions present in the excavation chamber. Moreover, many people in the workforce become de-acclimatized after several CA interventions, particularly during the winter months, requiring third-party staff (so-called "CA divers") to take over. Additional labor costs are as follows:

- Extra pay for contractor staff for working under compressed-air conditions
- Costs for third-party staff

For the purpose of pre-estimated, it is assumed that CA interventions are performed by a team of three workers, of whom two are part of the contractor workforce.

	Hazard pay	2 x 0.80 €/h	1.60 €/h
+	Extra pay for operating compression equipment	2 x 1.30 €/h	2.60 €/h
+	Extra pay for working under compressed-air conditions	2 x 5.75 €/h	11.50 €/h
+	Productivity bonus	20 % x 2 x 14.56 €/h	5.82 €/h
=	Extra pay contractor staff		21.52 €/h
+	Costs for third-party staff		60.00 €/h
			81.52 €/h

In order to determine the performance of the TBM, 8 % to 10 % of operating time for compressed-air interventions is assumed.

0.08 to 0.10 x 2,400 h = 192 to 240 h time apportioned for CA interventions

Assuming a performance rate of 2.5 h/m³ to break down boulders and blocks to stone-crusher size, the determined amount of hours equals a calculated obstacle value of

192 to 240 h/2.5 h/m³ = 75 to 100 m³ (rounded)

along the boring route. A mean value of 216 h is entered into the pre-estimate. However, this value includes working under CA conditions only, to which the transfer time (i.e. time spent in the decompression chamber) must be added. Transfer times can be neglected for the purpose of determining performance rates since boring work can continue while CA staff is inside the decompression chamber. Time spent in the decompression chamber usually amounts to about 50 % of time spent in the excavation chamber under CA conditions. Hence, the total amount of time required for a CA intervention is 216 h x 1.5 = 324 h, and additional costs come to 26,412.48 € with 81.52 € per hour spent working under CA conditions.

Equipment costs
Costs for tunnel boring machines

Equipment costs are determined taking into consideration the purchase and (re-)selling values for equipment in accordance with their respective performance rate calculations conducted by the tunnel contractor. Hence, the difference between purchase and (re-) selling values is the basis for determining equipment costs for the scheduled target operating time.

Thus, equipment costs per workday are calculated as follows:

$$E_{costs} = \frac{(P_{Buy} - P_{Re\text{-}sell})}{D_{Target}}$$

Key:

P_{Buy} = Purchase value of equipment in accordance with performance rate calculations

$P_{Re\text{-}sell}$ = Re-selling value of equipment in accordance with performance rate calculations

D_{Target} = Scheduled duration of the boring process

Further costs for assembly, disassembly, and transport of equipment should also be considered. Table 2.32 shows total costs for both tunnel boring machines:

Table 2.32 Designated costs for tunnel boring machine

Specifications							
Item	Qty.	Unit	Short description of operation				
	2	ea	Shipment, assembly, and disassembly of TBMs				
Unit costs							
Cost type	Qty.	Unit	Wage €/h	Equipment €/pc	Material €/pc	Misc. €/pc	Third-party €/pc
Purchase of TBM	1.00	ea		22,224,456.58			
Re-sale of TBM	1.00	ea		-4,843,015.79			
Delivery of TBM	1.00	ea					301,280.00
Assembly of TBM	4,000.00	h	39.29				
Disassembly of TBM	3,000.00	h	39.29				
Return of TBM	1.00	ea					256,654.74
Development costs	1.00	ea				2,171,052.63	
Standby components	1.00	ea		1,578,947.37			
Direct costs of partial services							

Unit costs			275,030.00	18,960,388.16	0.00	2,171,052.63	557,934.74	21,964,405.53 €/ea
Direct costs			550,060.00	37,920,776.32	0.00	4,342,105.26	1,115,869.48	43,928,811.06 €
Surcharge rates	in percent		12.00	12.00	12.00	12.00	12.00	
Surcharge			33,003.60	2,275,246.58	0.00	260,526.32	66,952.17	2,635,728.67€/ea
Unit price	**24600134,2**	**€/ea**			**Total**			**49,200,268.40 €**

Costs for separating, bentonite, and grouting facilities

Table 2.33 Additional facility costs for the TBM

Specifications								
Item	Amount	Unit	Short description of operation					
	1	ea	Delivery, assembly, disassembly of separation facility, bentonite facility, grouting facility					
Unit costs								
Cost type	Amount	Unit	Wage €/h	Equipment €/pc	Material €/pc	Misc. €/pc	Third-party €/pc	
Purchase of separation facility	1.00	ea		4,331,973.68				
Re-sale of separation facility	1.00	ea		-957,771.58				
Purchase of bentonite facility	1.00	ea		173,684.21				
Re-sale of bentonite facility	1.00	ea		-39,165.79				
Purchase of grouting facility	1.00	ea		657,894.74				
Re-sale of grouting facility	1.00	ea		-171,052.63				
Assembly of facility segments	1,200.00	h	39.29	36,514.01				
Disassembly of facility segments	900.00	h	39.29					
Transportation of facility segments	1	ea					69,998.34	
Direct costs of partial services								
Unit costs			82,509.00	4,032,076.64	0.00	0.00	69,998.34	4,184,583.98 €/ea
Direct costs			82,509.00	4,032,076.64	0.00	0.00	69,998.34	4,184,583.98 €
Surcharge rates	in percent		12.00	12.00	12.00	12.00	12.00	
Surcharge			9,901.08	483,849.20	0.00	0.00	8,399.80	502,150.08 €/ea
Unit price	**4.686,734.06 €/ea**				**Total**			**4.686,734.06**

Material costs

The majority of costs for construction materials are allocated for tunnel expansion and stability. Costs for boring with cutting shield and tunnel expansion with single-layer prefabricated segments (standard procedure for loose soil types as it is the most cost-efficient) as well as sustained grouting of annular clearance are as follows:

- Manufacture and delivery of tunnel segments including grouting
- Manufacture of grouting material

This includes costs for any materials that become components of the final construction. As the width of a tunnel ring segment is indicative of the forward expansion of a tunnel, any other costs for construction and auxiliary materials are calculated using length units of the tunnel. Any materials that do not become components of the final construction fall into the category of auxiliary materials. For the boring process with hydro cutting shield, bentonite slurry and greasing materials for the cutting shield tail are classified as auxiliary materials. Costs for the required air compression have to be considered as well. Costs for air compression are summarized under equipment costs since compressed air conditions are created via generators, which are either components of the TBM or separate facilities of the construction site. In the following, material and tunnel expansion costs correlate to running meter.

Costs for prefabricated ring segments

For the construction of the tunnel rings, reinforced concrete segments with a thickness of 30 cm made of a C45/55 concrete are used. Considering required size tolerances and a reinforcement value of 120 kg/m³, costs for manufacture and delivery of tunnel segments are calculated with 250.00 to 275.00 €/m³.

$A_{ring} = \pi \times (r^2_{outer} - r^2_{inner})$

$A_{ring} = \pi \times [(2.75\ m)^2 - (2.45\ m)^2] = 4.90\ m^2$

$V_{clearance} = 0.70\ m \times 0.15\ m \times 0.90\ m \times 12 = 1.13\ m^3$

$V_{ring} = A_{ring} \times 1.50\ m - V_{clearance}$

$V_{ring} = 4.90\ m^2 \times 1.50\ m - 1.13\ m^3 = 6.22\ m^3$

$K_{segments} = 6.22\ m^3/ring / 1.50\ m/ring \times 262.50\ €/m^3 = 1{,}088.50\ €/m$

Costs of sealing gaskets

Neoprene sealing gaskets, which are delivered and assembled separately, are employed for the tunnel segments. Considering a groove base width of 33 mm and groove depth of 15 mm, a base price to the amount of 2.90 €/m for sealing gaskets along the circumference and additional 0.20 €/m for adhesive components can be assumed.

6 segments + 1 capstone with sealing gaskets along the circumference:

7 segments x 1.50 m x 2 = 21.00 m

$\pi \times 5.20\ m \times 2$ = 32.70 m (rounded)

Total length per ring = 53.70 m

$K_{sealing}$ = 53.70 m/ring/1.50 m/Ring x 3.10 €/m = 110.98 €/m

Costs of grouting materials

A mixture of grouting materials appropriate for gravelly soils was chosen. For the calculation, an average annular clearance of 15 cm is assumed. Base costs for respective components are equal to commercial prices. The calculated ratio of mixed materials is as follows:

Table 2.34 Grouting components

Component	Mass percentage	Gross density	Costs
Cement	4	3.10 kg/dm³	85.00 €/t
Sand	58	2.50 kg/dm³	15.00 €/t
Filling material	25	2.70 kg/dm³	32.50 €/t
Bentonite	1	1.70 kg/dm³	140.00 €/t
Water	12	1.00 kg/dm³	2.75 €/t

Costs for one cubic meter of grouting material are calculated as follows:

Cement	= 0.04 x 3.1 kg/dm³ x 85.00 €/t	=	10.54 €/m³
Sand	= 0.58 x 2.5 kg/dm³ x 15.00 €/t	=	21.75 €/m³
Filling material	= 0.25 x 2.7 kg/dm³ x 32.50 €/t	=	21.94 €/m³
Bentonite	= 0.01 x 1.7 kg/dm³ x 140.00 €/t	=	2.38 €/m³
Water	= 0.12 x 1.0 kg/dm³ x 2.75 €/t	=	0.33 €/m³
Total			**56.94 €/m³**

Resulting consumption per meter of length in accordance with the above calculations is as follows:

$V_{grout} = \pi \text{ x } (r^2_{outer} - r^2_{inner}) \text{ x } 1.00 \text{ m}/1.00 \text{ m}$

$V_{grout} = \pi \text{ x } [(2.85 \text{ m})^2 - 2.60 \text{ m}^2)] \text{ x } 1.00 \text{ m}/1.00 \text{ m} \quad = \quad 4.30 \text{ m}^3/\text{m}$

$K_{grout} = 4.30 \text{ m}^3/\text{m x } 56.94 \text{ €}/\text{m}^3 \quad = \quad 244.84 \text{ €}/\text{m}$

Total expansion costs amount to:

$K_{exp} = K_{segments} + K_{seal} + K_{grout}$

$K_{exp} = 1{,}088.50 \text{ €}/\text{m} + 110.98 \text{ €}/\text{m} + 244.84 \text{ €}/\text{m} \quad = \quad 1{,}444.32 \text{ €}/\text{m}$

Costs of auxiliary materials

Costs of bentonite

Bentonite demand and consumption is subject to varying fluctuations with differing geological conditions, which increases the difficulty of estimating and calculating these values. Given a boring diameter of 5.65 m and gravelly soil conditions, a base consumption value of 0.25 t/m can be assumed.

$K_{bentonite} = 160.00 \text{ €}/\text{t x } 0.25 \text{ t}/\text{m} \quad = \quad 40.00 \text{ €}/\text{m}$

Costs of cutting shield tail grease

In order to reduce friction between shield tail gaskets and tunnel segment ring, the shield tail is persistently greased along its circumference. Consumption, in this case, amounts to roughly 7 kg/m with a price of 50 € per 32-kg barrel. The relevant costs are as follows:

$$K_{grease} = 50.00\ €/32\ kg \times 7\ kg/m \qquad = \qquad 10.94\ €/m$$

With additional miscellaneous material costs of:

$$K_{misc} = K_{bentonite} + K_{grease}$$

$$K_{misc} = 40.00\ €/m + 10.94\ €/m \qquad = \qquad 50.94 €/m$$

Table 2.35 Calculation of material costs of bentonite and cutting shield tail grease

Specifications								
Item	Qty.	Unit	Short description of operation					
	1	m	Material costs for bentonite and shield lubrication					
Unit costs								
Cost type	Qty.	Unit	Wage €/h	Equipment €/Unit	Material €/Unit	Misc. €/Unit	Thirdparty €/Unit	
Grease material for shield tail	7.00	kg			50 €/32 kg			
Bentonite	0.25	t			160.00			
Direct costs of partial services								
Unit costs			0.00	0.00	50.94	0.00	0.00	50.94 €/m
Direct costs			0.00	0.00	50.94	0.00	0.00	50.94 €
Surcharge rates	in percent		12.00	12.00	12.00	12.00	12.00	
Surcharge			0.00	0.00	6.11	0.00	0.00	6.11 €/m
Unit price	**57.05 €/m**				**Total**			**57.05 €**

Costs for disposal of excavated materials

Usually, a subcontractor is tasked with the disposal of excavated materials. Disposal costs are billed in €/m³ or €/t whereas they consist of loading and off-loading, net transport costs, and disposal site fees. The main parameters for the calculation of disposal costs are distance between disposal and construction site and quality of excavated materials.

Table 2.36 Calculation of disposal costs for excavated materials

Specifications									
Item	Qty.	Unit	Short description of operation						
	3,2340.00	m^3	Disposal of excavated material						
Unit costs									
Cost type		Qty.	Unit	Wage €/h	Equipment €/Unit	Material €/Unit	Misc. €/Unit	Third-party €/Unit	
Loading and unloading		1.00	m^2					0.23	
Transportation costs		1.00	m^2					2.00	
Disposal site fees		1.00	m^2					15.00	
Direct costs of partial services									
Unit costs				0.00	0.00	0.00	0.00	0.00	17.23 €/m^3
Direct costs				0.00	0.00	0.00	0.00	0.00	557,218.20 €
Surcharge rates	in percent			12.00	12.00	12.00	12.00	12.00	12.00
Surcharge				0.00	0.00	0.00	0.00	0.00	2.07 €/m^3
Unit price	**19.30 €/m^3**					**Total**			**624,162.00 €**

2.5.3 Example of traditional tunnel construction

2.5.3.1 Specifications

As part of a measure to decrease traffic congestion in an inner-city area, it is intended to divert a street car line from the intersection area into a tunnel structure. The initial construction site is created openly. Slurry walls are produced to enclose the construction pit.

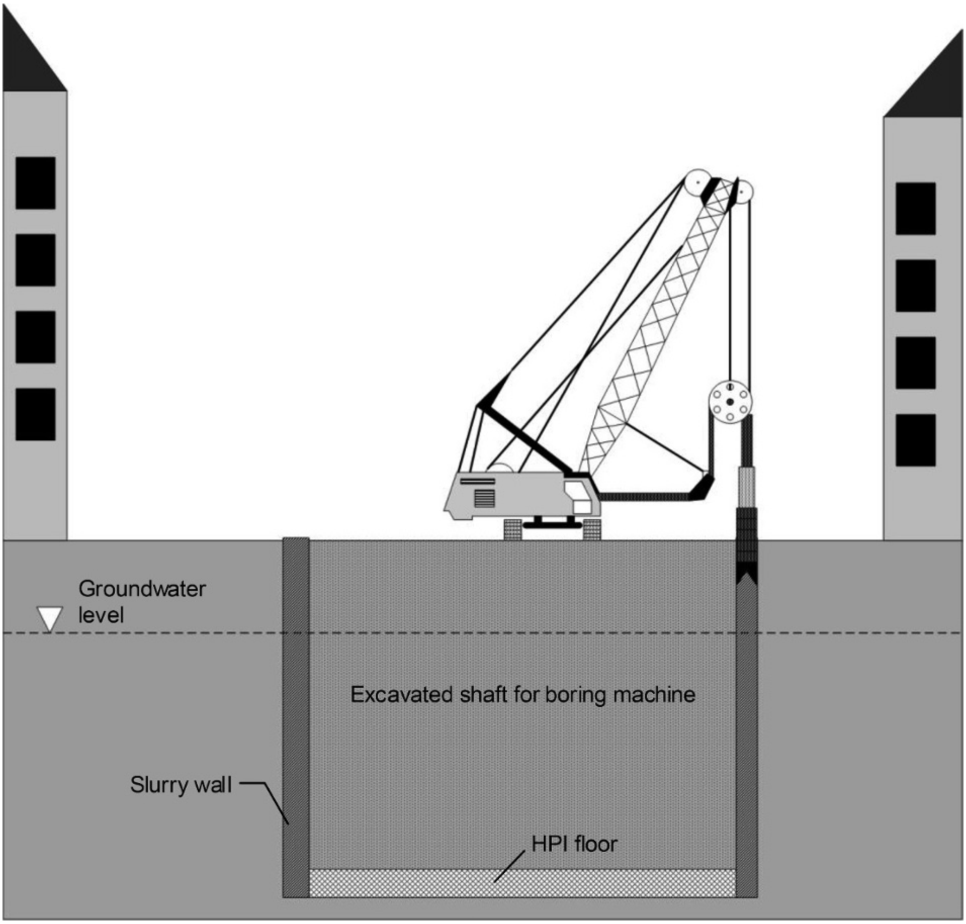

Figure 2.18 Construction stage – Slurry wall production

Excavation of soil follows creation of a temporary cover of reinforced concrete and subsequent reintegration of soil materials.

Before excavations can begin, a preliminary protective area is assembled into the construction pit, which artificially freezes groundwater, thus waterproofing and stabilizing the construction pit ground. In order to introduce the required freezing pipes, microtunnels are bored into the construction pit from the neighboring construction site. These microtunnels contain pipes for the delivery of brine solutions required to create the protection area. The protection area has a total length of about 50 m. Microtunnels carrying the freezing agent pipes run through the area's east end wall, designated as a slurry wall, which waterproofs the structure to a depth of 1.0 m. Following is an overview of operations required for manufacture and maintenance of the freezing area in accordance to the employed freezing procedure (brine freezing):

– Microtunneling for freezing and temperature measuring pipes
– Boring procedures for assembly of freezing pipes as well as temperature measuring pipes
– Creation of freezing system including installation of all required facility components e. g. freezing and temperature measuring pipes, freezing equipment, supply pipes etc.
– Freezing of area and maintenance during various freezing stages
– Organization and realization of measuring programs
– Monitoring operations

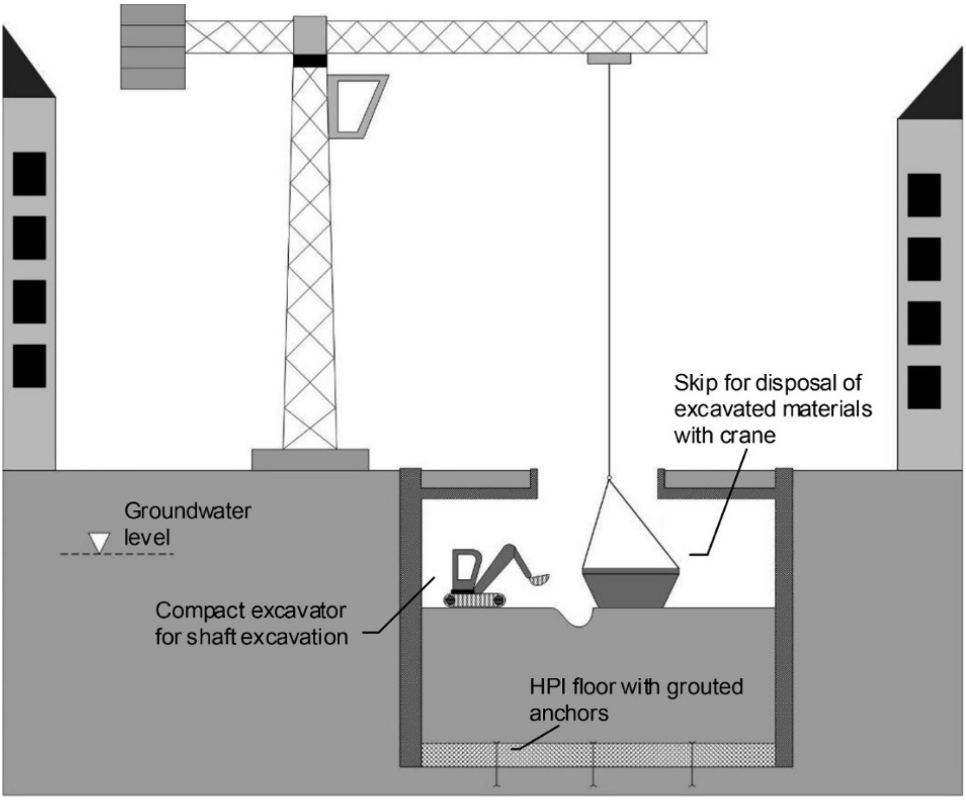

Figure 2.19 Construction stage – Excavation of entrance shaft

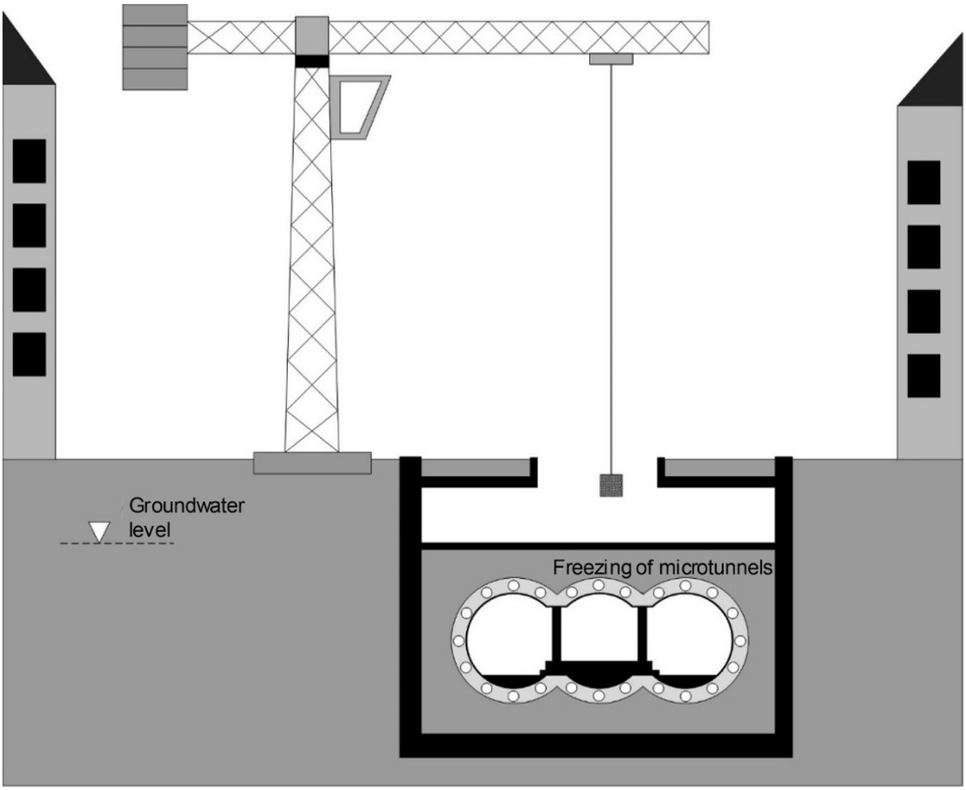

Figure 2.20 Construction stage – Microtunnelling

The artificially frozen area has to meet the following minimum requirements independent of any further construction or stability requirements:

– The frozen area has to be completely watertight over the total freezing period
– The area has to be stable and structurally sound. Watertight connectivity of the frozen area to entrance and exit walls of boring areas is to be ensured

After creation of the freezing area, boring processes are realized, and the excavated chamber is lined with reinforced shotcrete. The shotcrete shell is hardened for a certain period of time. It has to be considered that the frozen area along the circumference of the shotcrete shell possesses merely sealing qualities after hardening due to deformation processes and related decline in rigidity.

The final tunnel expansion with reinforced concrete (inner tunnel shell) is to be viewed as the actual tunnel structure with respect to stability/rigidity and operational serviceability. Hence, this type of construction follows the basic principle of separating capacities regarding diversion/dissipation of loads and sealing:

– During the period between boring and hardening of the outer shell (shotcrete shell), the artificially frozen area serves as barrier to offset earth and hydraulic pressure and seals the excavated chamber against groundwater.

– The outer shotcrete shell does not possess sealing qualities but secures the excavated chamber. Assessments regarding dimensions of the outer shell are made under assumption of maximum earth and hydraulic pressure.
– After installation of the inner shell and defrosting of the artificially frozen area, the inner shell takes on capacities for both sealing the chamber and bearing/dissipating loads.

2.5.3.2 Construction schedule

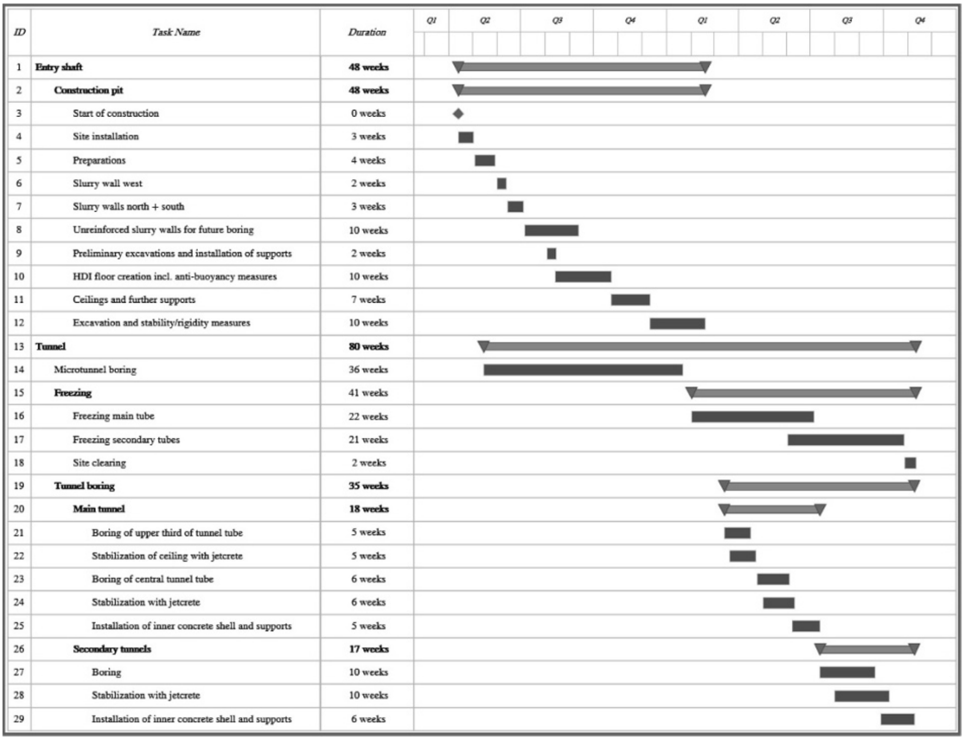

Figure 2.21 Schedule for boring and microtunnel boring processes

2.5.3.3 Determination of costs and pricing

Construction site facilities
Construction site facilities required for the realization of microtunnel boring processes following the example of microtunnel boring are as follows:

– Setting up a construction site
– Assembly and installation of sealing gaskets for boring procedures
– Assembly and installation of rigidity structures (abutment elements) for boring equipment (press frame)
– Installation of TBM and any required equipment and auxiliary devices. Installation and calibration of measuring systems required for microtunnel boring.

After the slurry wall is integrated and microtunnel boring devices installed into the unreinforced slurry wall, designated as entrance point, a watertight connection between machine shell and excavation recess is created. Subsequently, the following construction site operations are required:

- Detachment and disassembly of the boring machine
- Permanent, watertight isolation of microtunnels in the area of the soil face (waterproofing of pipes)
- Reorientation of boring devices and hydraulic presses to the next boring entrance

Figure 2.22 details the section of exemplary construction site facilities for microtunnel boring.

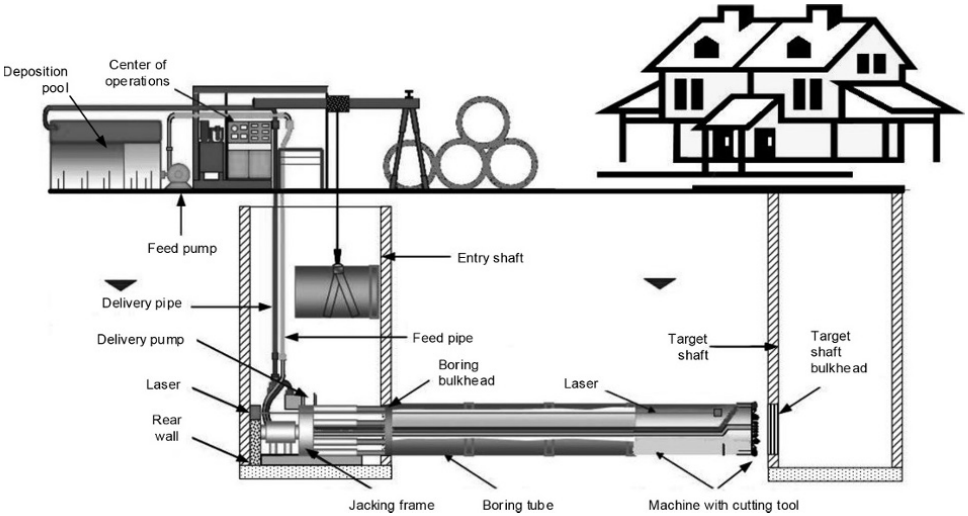

Figure 2.22 Section of entrance shaft construction site facilities

The following calculation assumes an average wage value of 39.00 €/h for assembly/disassembly operations. Costs include planning of supporting structures and abutments.

Table 2.37 Calculation of construction site facilities

Specifications			
Item	Amount	Unit	Short description of operation
	1.00	ea	Construction site facilities

Unit costs

Cost type	Amount	Unit	Wage €/h	Equip-ment €/Unit	Material €/Unit	Misc. €/Unit	Third-party €/Unit
Initial assembly: Assembly of equipment ready for operations 6 employees x 15 d x 10 h/d	900.00	h	39.00	6,000.00	4,000.00		5,000.00
Disassembly ready for transportation: Disassembly of equipment 4 empl. x 10 d x 10 h/d	400.00	h	39.00	3,000.00	1,500.00		
Transportation to and from site 2 x 10 pieces x 500.--							10,000.00
Installation of general construction site, materials etc. 4 empl. x 5 d x 10 h/d	200.00	h	39.00	3,000.00	5,000.00		2,500.00
Clearing of general construction site, materials etc.	120.00	h	39.00	500.00			500.00
Structural analysis and operational scheduling for support structures and abutments							10,000.00
Assembly of support structure for entry shaft 6 empl. x 6 d x 10 h	360.00	h	39.00	8,000.00	5,000.00		
Rental fees for support structures and abutments 4 mo x 350 t x 80.--				20,000.00			
Disassembly of support structures 6 empl. x 4 d x 10 h/d	240.00	h	39.00	9,000.00			
Initial assembly of abutments 5 empl. x 10 d x 10 h/d	500.00	h	39.00				
Disassembly of abutments 5 empl. x 6 d x 10 h/d	300.00	h	39.00				
Assembly of boring bulkheads 30 segments x 2 empl. x 2 h/segment	120.00	h	39.00				

Retraction of TBM: 30 segments x 3 empl. x 10 h/segment	900.00	h	39.00					
Grouting of target slurry wall: 30 segments x 3 empl. x 1.5 h Material 30 segments x 250.--	135.00	h	39.00					
Total attrition of cutting devices 8 batches x 21,809.--					174,472.00			
Machine insurance 4 Mon x 2,545.00 x 0.0145							147,610.00	
Site management during site (de)installation 2 empl. x 6,500.--/mo						13,000.00		
Site management during boring 1 manager per machine (30 x 50 m/(2 x 6m/d)/30d/mo) x 6,500.--/mo						27,083.33		
Site management machine operator 4 mo x8,500.--/Mon x 75 %						25,500.00		
Direct costs of partial services								
Unit costs			162,825.00	49,500.00	189,972.00	65,583.33	175,610.00	643,490.33 €/ea
Direct costs			162,825.00	49,500.00	189,972.00	65,583.33	175,610.00	643,490.33 €
Surcharge rates		in percent	12.00	12.00	12.00	12.00	12.00	
Surcharge			19,539.00	5,940.00	22,796.64	7,870.00	21,073.20	77,218.84 €/ea
Unit Price		**714,812.37 €/ea**			**Total price**			**714,812.37 €**

Disposal of excavated materials during microtunnel construction

Delivery (i.e. removal) of excavated materials is realized through hydraulic slurry. Within certain limitations, it should be possible to break and remove obstacles in the accessible excavation chamber during the boring process. Hence, this process assumes hydraulic excavation in conjunction with separation and slurry recycling facilities. In accordance with the present geological conditions, separation facilities consist of multi-stage sieves and filters containing shaking screens, centrifuges, chamber filters, and conveyor belt compactors etc. Gravel and sand are separated from fines as well as possible. The contractor is to be informed about the proper disposal in accordance with regulations and has to receive respective documented verification (disposal documents, receipts, weigh station documents). Furthermore, the contractor has to be instructed about the selected disposal procedure during contractual negotiations. Any costs with respect to disposal need to be itemized accordingly and are not reimbursed separately.

Costs accrued for separation of waste materials are also not reimbursed separately and have to be itemized accordingly. Disposal costs of the designated waste management service provider are paid by the contractor and later reimbursed by the contractor without additional administrative charges if properly documented. In order to calculate disposal costs for excavated materials during microtunnel construction, the total sum of the operational performance for this process is determined first. A total of 30 microtunnels are processed in accordance with figure 2.23.

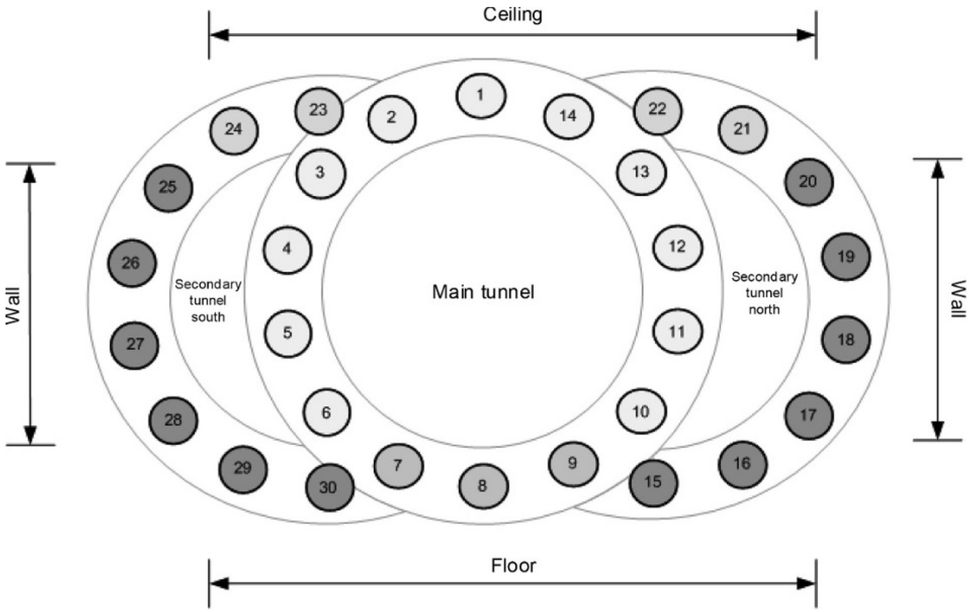

Figure 2.23 Schematic section of boring area

The volume of a microtunnel with an outer diameter of the pipe of 1.59 m and average length of 52 m is determined as follows:

$$A_{microtunnel} = P \text{ x } d^2/4$$

$$A_{microtunnel} = P \text{ x } (1.59 \text{ m})^2/4 = 1.99 \text{ m}^2$$

$$V_{microtunnel} = A_{microtunnel} \text{ x } L$$

$$V_{microtunnel} = 1.99 \text{ m}^2 \text{ x } 52.00 \text{ m} = 103.48 \text{ m}^3$$

As a total of 30 microtunnels are processed and wet weight amounts to 1.94 t/m³, the total amount of disposable materials is as follows:

$$m_{tot.\ microtunnels} = V_{microtunnel} \text{ x } 30 \text{ tunnels x } 1.94 \text{ t/m}^3$$

$$m_{tot.\ microtunnels} = 103.48 \text{ m}^3 \text{ x } 30 \text{ x } 1.94 \text{ t/m}^3 = 6{,}022.54 \text{ total}$$

Table 2.38 Calculation of amount of excavated materials during microtunnel construction

Specifications								
Item	Qty.	Unit	Short description of operation					
	1	t	Disposal of material excavated via micro tunnel driving					
Unit costs								
Cost type	Qty.	Unit	Wage €/h	Equipment €/Unit	Material €/Unit	Misc. €/Unit	Third-party €/Unit	
General disposal costs	1.00	t					7.50	
Transportation	1.00	t					1.39	
Disposal costs for non-rein-forces concrete Z0	1.00	t					0.59	
Direct costs of partial services								
Unit costs			0.00	0.00	0.00	0.00	9.48	9.48 €/t
Direct costs			0.00	0.00	0.00	0.00	98,781.71	98,781.70 €
Surcharge rates	in percent		12.00	12.00	12.00	12.00	12.00	
Surcharge			0.00	0.00	0.00	0.00	1.14	1.14 €/t
Unit price	**10.62 €/t**				**Total**		**110,660.53** €	

Costs of downtimes

In the following paragraphs, calculations are performed for costs arising in the unlikely event of complete downtime of the TBM including operational and overhead personnel costs.

Table 2.39 Calculation of downtime costs

Specifications								
Item	Qty.	Unit	Short description of operation					
	1	d	Boring downtimes					
Unit costs								
Cost type	Qty.	Unit	Wage €/h	Equipment €/Unit	Material €/Unit	Misc. €/Unit	Third-party €/Unit	
Equipment	1.00	d		6,200.00				
Personnel 2 x 3 empl. x 9h	54.00	h	39.00					
Site management 2 workers x 5,900 €/mo/21.7 WD/mos	1.00	d				543.78		
Machine engineer 1 worker x 5,900 €/mo/21.7 WD/mo	1.00	d				271.89		
Project management 40 % x 8.200€/mo/21.7 WD/mo	1.00	-				151.15		
Rental fees for support structures 340 t x 75€/(t and mo)/30.4 CD	1.00	-		838.82				
Electricity, Diesel reduced to 70 %	1.00	d			680.00			
Small equipment reduced to 70 %	1.00	d		210.00			1.39	
* 52 CW/12 mo x 5 WD/CD = 21.7 WD/mo, 365 CD/12 mo = 30.4 CD/mo								
Direct costs of partial services								
Unit costs			2,106.00	7,248.82	680.00	966.82	0.00	11,001.64 €/d
Direct costs			2,106.00	7,248.82	680.00	966.82	0.00	11,001.64 €
Surcharge rates	in percent		12.00	12.00	12.00	12.00	12.00	
Surcharge			252.72	869.86	81.60	116.02	0.00	1,320.20 €/d
Unit price	**12,321.84 €/d**				**Total**			**12,321.84 €**

Boring process for microtunnels

For the construction of the tunnel, 30 microtunnels with an outer diameter of 1.5 m are created. Boring processes are performed over a distance of about 50 m, which are finalized at a previously integrated, partially unreinforced slurry wall. The microtunnels are watertight, precise constructions, contained by steel pipe. The planning for the microtunnels includes curvatures in level as well as inclined areas along the pipeline.

Table 2.40 Calculation of costs for microtunnel boring

Specifications

Item	Qty.	Unit	Short description of operation
	30	ea	Microtunnel boring

Unit costs

Cost type	Qty.	Unit	Wage €/h	Equipment €/Unit	Material €/Unit	Misc. €/Unit	Third-party €/Unit
Scheduled length: 50.00 m, boring rate: 6 m/shift							
Personnel 3 workers. x 9 h : 6 m/shift x 50 m	225.00	h	39.00				
Equipment (cf. attachment) 50 m : (2 x 6 m/WD)	4.17	d					
Pipe delivery	50.00	m			450.00		
Bentonite 3.14 x 1.59 x 0.04 x 50 m x 0.1t/m³	1.00	t			428.72		
Insulation 3.14x1.59 x 0.04 x 50 m x 0.9t/m³	8.99	t			100.00		
Welding material 12 pipes x 137.50	12.00	ea			137.50		
Sealing material 6.-- x 50	50.00	m			6.00		
Electricity/Diesel 50 m x 1000.--/d/(2 x 6 m/d)	4.17	d			1,000.00		
Engineering of end caps 943.20/30	1.00	-				31.44	

Direct costs of partial services

	Wage	Equipment	Material	Misc.	Third-party	
Unit costs	8,775.00	25,833.33	29,943.42	31.44	0.00	64,583.19 €/ea
Direct costs	263,250.00	775,000.00	898,302.60	943.20	0.00	1,937,495.80 €
Surcharge rates in percent	12.00	12.00	12.00	12.00	12.00	
Surcharge	1,053.00	3,100.00	3,593.21	3.77	0.00	7,749.98 €/ea
Unit price 72,333.17 €/ea			**Total**			**2,169,995.20 €**

Redeployment

Table 2.41 Calculation of costs for staff and equipment redeployment

Specifications			
Item	Amount	Qty.	Short description of operation
	29	ea	Redeployment of equipment

Unit costs								
Cost type	Qty.	Unit	Wage €/h	Equipment €/Unit	Material €/Unit	Misc. €/Unit	Third-party €/Unit	
Personnel 3 empl. x 11 h/shift x 2 shifts	66.00	h	39.00					
Equipment 6200.--/d x 1 d	1.00			6,200.00				
Material = 1/29 of 20,930.-- x 0.5	1.00			360.86				
Electricity/Diesel	1.00			750.00				
Direct costs of partial services								
Unit costs			2,574.00	7,310.86	0.00	0.00	0.00	64,583.19 €/ea
Direct costs			74,646.00	7,310.86	0.00	0.00	0.00	1,937,495.80 €
Surcharge rates	in percent		12.00	12.00	12.00	12.00	12.00	
Surcharge			308.88	877.30	0.00	0.00	0.00	1,186.18 €/ea
Unit price	**11,071.04 €/ea**				**Total**			**321,060.16 €**

Additional pay for rock extrication and obstacles

According to preliminary soil and ground surveys, present geological conditions for the example construction herein indicate that soils consist primarily of sands, gravels, and boulder clays with embedded rocks and rock blocks. Moreover, artificial obstacles and structural construction remains can be expected during excavation. Additional costs arising due to disposal of natural and artificial obstacles in the artificial freezing area are reimbursed separately by the contractor.

Table 2.42 Rock extrication and costs for the disposal of obstacles

Specifications			
Item	Qty.	Unit	Short description of operation
	1.00	per shift/ per hour	Additional costs for rock excavation and obstacles

Unit costs								
Cost type	Qty.	Unit	Wage €/h	Equipment €/Unit	Material €/Unit	Misc. €/Unit	Third-party €/Unit	
Estimated number of obstacles: 0.5 pieces per boring segment								
Boring team (time for initial extrication attempts and reporting only): 3 people x 2 h	6.00	h	39.00					
Equipment (6.200,--/22 h/d) x 2h	1.00	-		563.64				
Material 300,--/h x 2h	1.00	-			600.00			
Electricity, Diesel: 2x (750,--/22 h/d)		-			68.18			
Additional effort for rock extrication assuming that total extrication time = ½ hour								
Boring team 3 workers x 12 h	36.00	h	39.00					
Equipment 6200,-- x 0,5	1.00	-		3,100.00				
Material 300,--/h x 12h	1.00	-			3,600.00			
Electricity, Diesel 750,--/2	1.00	-			375.00			
Additional extrication effort. Mobilisation 3 workers x 12 h	36.00	h	39.00					
Additional extrication effort. Employment of compressed-air physician.	1.00	-					1,500.00	
General rock extrication effort								
Provision of extrication equipment	1.00	-		38,933.33				
Briefing of compressed air physician	1.00	-					400.00	
Availability of compressed air physician	1.00	-					7,000.00	
Direct costs of partial services								
Unit costs			3,042.00	72,596.97	4,643.18	0.00	8,900.00	89,182.15 €
Direct costs			3,042.00	72,596.97	4,643.18	0.00	8,900.00	89,182.15 €
Surcharge rates		in percent	12.00	12.00	12.00	12.00	12.00	
Surcharge			365.04	8,711.64	557.18	0.00	1,068.00	10,701.86 €
Unit price per shift		**99,884.01 €**			**Total per shift (9 h)**			**99,884.01 €**
Unit price per h		**11,098.22 €**			**Total per hour**			**11,098.22 €**

Disposal of excavated materials during boring processes

As per contractual regulations, workable soil becomes property of the contractor. Construction debris and unworkable soil has to separated, removed, and disposed according to legal requirements. Payments are determined in conjunction with the original weigh station documents, provided by the respective waste management facility, and required delivery slips. Documents have to be provided to the client a day after disposal of materials by the contractor at the latest. Expenditures for separating of waste materials are not reimbursed separately and have to be itemized accordingly. Disposal costs of the designated waste management service provider are paid by the contractor and later reimbursed by the client without additional administrative charges if properly documented.

Table 2.43 Calculation of costs for disposal of excavated materials

Specifications								
Item	Qty.	Unit	Short description of operation					
	35,365.51	t	Disposal of material excavated during boring operations					
Unit costs								
Cost type	Qty.	Unit	Wage €/h	Equipment €/Unit	Material €/Unit	Misc. €/Unit	Third-party €/Unit	
Disposal of excavated material, General salary	0.0065	h/t	39.00					
Disposal of excavated material, Salary locksmith	0.0007	h/t	39.00					
Auxiliary materials Grouting materials	0.0230	kg			0.90			
Subcontractor‘s costs; General disposal	1.00	t			9.99			
Subcontractor‘s costs; Transport, loading, unloading	1.00	t			3.76			
Direct costs of partial services								
Unit costs			0.28	0.00	13.77	0.00	0.00	14.05 €/t
Direct costs			9,930.64	0.00	487,007.83	0.00	0.00	496,938.47 €
Surcharge rates		in percent	12.00	12.00	12.00	12.00	12.00	
Surcharge			0.03	0.00	1.65	0.00	0.00	1.68 €/t
Unit price		**15.73 €/t**			**Total**			**556,299.47 €**

Boring processes for the main tunnel body

After microtunnels have been created, freezing facility installed, and freezing area de-frosted, excavation of the main tunnel, with the construction pit as entrance shaft, and integration of the inner shell together with both support rows can begin. Boring procedures are performed in different geological strata, mostly sands and, to a lesser extent, boulder clays, described in the soil and ground surveys. Shotcrete rebound has to be removed, transported, and disposed (without compensation) by the contractor and must not be recycled. Costs for the main tunnel are as follows:

Table 2.44 Calculation of costs for main tunnel body

Specifications									
Item	Qty.	Unit	Short description of operation						
	1.00	ea	Tunnel boring, main tunnel						
Unit costs									
Cost type	Qty.	Unit	Wage €/h	Equipment €/Unit	Material €/Unit	Misc. €/Unit	Third-party €/Unit		
Boring rate in non-frozen sand/gravel/rock/clay, Wages (construction of upper third of tunnel tube) 120.00 gang h x 5.00 workers/gang	600.00	h	39.00						
Boring rate in frozen sand/gravel or clay, Wages (construction of upper third of tunnel tube) 292.00 gang h x 5.00 workers/gang	1,460.00	h	39.00						
Boring rate in frozen clay, Wages (construction of upper third of tunnel tube) 56.00 gang h x 5.00 workers/gang	280.00	h	39.00						
Boring rate in frozen clay, Wages (construction of upper third of tunnel tube) 6.0 h/workers x 5 workers/gang x 70.0 gang h	140.00	h	39.00						
Boring rate in frozen rock, Wages (construction of upper third of tunnel tube) 6.0 h/workers x 5 workers/gang x 28.00 gang h	390.00	ea	39.00						
Attrition of cutting devices 50.00 m x 143.85 €/m	50.00	m		143.85					
Redeployment of excavation equipment, Wages (construction of upper third of tunnel tube), 6.0 h x 5 workers x 53.0 gang h	50.00	m		59.98					
Disassembly of shotcrete shell, Wages (construction of upper third of tunnel tube) 6.0 h x 5 workers x 94.0 gang h	1.49	ea		1,900.00					
Redeployment of excavation and disposal equipment Wages (construction of upper third of tunnel tube) 6.0 h x 5 workers/gang x 14.0 gang h	5.84	ea		1,038.13					

Deinstallation of microtunnel boring pipes, Wages (construction of upper third of tunnel tube) 6.0 h x 5 workers/gang x 54.0 gang h	1.12	ea		1,038.13				
Deinstallation of MT boring pipes, attrition	100.00	m		85.29				
Deinstallation of MT boring pipes, attrition of excavator teeth	100.00	m		35.54	0.10			
Excavation of sand/rock/clay, attrition of excavator teeth	6,857.25	ltr			0.91			
Night shifts, Wages (working underground, general operations) 4.80 h/m x 50.00m	240.00	h	39.00					
Night shifts, auxiliary materials	50.00	m			90.60			
Shotcrete material for tunnel 50 x 32.7m²/m tunnel wet shotcrete 0.518 m3/m2 x 61.61 €/m3	1,638.00	m²			31.91			
Shotcrete material for tunnel 50 x 32.7m²/m tunnel, flowing concrete 4.14 kg/m² x 0.95 €/kg	1,638.00	m²			3.93			
Shotcrete material for tunnel 50 x 32.7m²/m tunnel delvocrete 0.621 kg/m² x 2.08 €/kg	1,638.00	m²			1.29			
Shotcrete material for tunnel 50 x 32.7m²/m tunnel, alkali-free accelerant 12.42 kg/m² x 0.59 €/kg	1,638.00	m²			7.33			
Shotcrete power, electricity incl. lubricants 9.418 kWh/m² x 0.10 € kWh	1,638.00	m²			0.94			
Shotcrete – attrition, attrition of shotcrete parts 0.776 1/m² x 3.17 €	1,638.00	m²			2.46			
Disposal of rebound materials and shotcrete, Diesel and lubricants 0.108 l/m² x 0.91 €/l	1,638.00	m²			0.10			
Disposal of rebound materials and shotcrete, disposal 0.135 m³/m² x 0.91 €/m³	1,638.00	m²			0.12			
Support arches 3.333 m/m x 1.81 €/m	50.00	m			6.03			
Support arches 2.333m/m x 4.53 €/m	50.00	m			10.57			
Support arches 1.333 m/m x 30.80 €/m	50.00	m			41.06			

Support arches 0.41 t/m x 724.80 €/t	50.00	m			297.17			
Reinforcement structural steel grid BSt M, without installation 0.409 t/m x 471.12 €/t	50.00	m			192.69			
Reinforcement, auxiliary materials	50.00	m			9.06			
Water supply pipes DN80, water supply pipes	50.00	m			23.58			
Fixtures, suspensions etc., auxiliary materials	50.00	m			4.53			
Unit costs		121,290.00	32,330.88	118,769.64	0.00	0.00	121,290.00	272,390.52 €/ea
Direct costs		121,290.00	32,330.88	118,769.64	0.00	0.00	121,290.00	272,390.52 €
Surcharge rates	in percent	12.00	12.00	12.00	12.00	12.00	12.00	
Surcharge		14,554.80	3,879.71	14,252.36	0.00	0.00	14,554.80	32,686.86 €/ea
Unit price	**305,077.38 €/ea**				**Total**			**305,077.38** €

Boring of secondary tunnels

After excavation of the main tunnel and integration of the shotcrete shell, creation of artificial freezing areas for both secondary tunnels begins in ta+ndem with the creation of the main tunnel. In order to maintain a freezing area, which runs along the circumference of both main and secondary tunnels, freezing pipes of the main tunnel are deactivated, and secondary tunnel freezing pipes activated. Pipes of the secondary microtunnels, a total of eight that intersect with the main tunnel, are removed as a result. The pipes contain the freezing lines and are filled with insulation materials. Prior to their removal, it is necessary to rinse the freezing lines (brine lines) and dispose of the rinsing fluids in accordance with legal requirements. In particular, quality requirements of introduced water and provisions by the local water authority have to be considered. The tunnel walls of the main tunnel are removed during the creation of the secondary tunnels. Due to structural requirements and earth pressure, supports have to bear significantly more load during this stage, and any emerging excavation difficulties have to be taken into account.

Table 2.45 Calculation of costs for secondary tunnels

Specifications			
Item	Qty.	Unit	Short description of operation
	1.00	ea	Tunnel boring, secondary tunnels

Unit costs

Cost type	Qty.	Unit	Wage €/h	Equipment €/Unit	Material €/Unit	Misc. €/Unit	Third-party €/Unit
Wages (construction of upper third of tunnel tube, excavation) 47.00 h/m x 100.00 m	47.00	h	39.00				
Boring rate in non-frozen sand/gravel/clay, Wages (construction of upper third of tunnel tube) 6.0 h/gang hours x 137.0 gang h	822.00	h	39.00				
Boring rate in frozen sand/gravel/clay, Wages (construction of upper third of tunnel tube) 6.0 h/gang h x 334.0 gang h	2004.00	h	39.00				
Boring rate in frozen clay, Wages (construction of upper third of tunnel tube) 6.0 h/gang h x 70.0 gang h	420.00	h	39.00				
Boring rate in frozen rock, wages (construction of upper third of tunnel tube) 6.0 h/gang h x 28.00 gang h	840.00	h	39.00				
Rocks and rock blocks separately Wages (construction of upper third of tunnel tube)	0.00	h	39.00				
Redeployment time of cutting devices Wages (construction of upper third of tunnel tube) 6.0 h/gang h x 53.0 gang h	318.00	h	39.00				
Disassembly of shotcrete shell Wages (construction of upper third of tunnel tube) 6.0 h/gang h x 94.0 gang h	564.00	h	39.00				
Redeployment time of cutting and excavation equipment Wages (construction of upper third of tunnel tube) 6.0 h/gang h x 14.0 gang h	84.00	h	39.00				
Deinstallation of microtunnel boring pipes, Wages (construction of upper third of tunnel tube) 6.0 h/gang h x 54.0 gang h	324.00	h	39.00				
Deinstallation of MT boring pipes, attrition	100.00	m		85.29			

Deinstallation of MT boring pipes, attrition of excavator“	100.00	m		35.54				
Excavation of sand/rock/clay, attrition of excavator teeth 0.0005 piece/m³ x 3,403.0 m³	1.70	ea		1,900.00				
Milling of frozen sand, attrition 0.004 piece/m³ x 1,667.0 m³“	6.67	ea		1,038.13				
Milling of boulder clay, attrition 0.04 piece/m³ x 35.0 m³	1.40	ea		1,038.13				
Crushing of rock blocks, attritions of excavator teeth 8.827 piece/m³ x 7.0m³	61.79	ea		2.72				
Extra collet for excavator for concrete removal, attrition 1.92 €/m³ x 94.0 m³	1.00	-		180.48				
Extra collet for excavator for concrete removal, attrition of digging teeth 1.71 €/m³ x 94.0 m³	1.00	-		160.74				
Energy electricity, electricity incl. lubricants 1,601.73 kWh/m x 0.10 €/kWh	100.00	m			160.17			
Energy Diesel, Diesel incl. lubricants 82.087 l/m x 0.91 €/l	100.00	m			74.70			
Wages for subsequent work, general underground work 2.4 h/m x 100.0m	240.00	h	39.00					
Subsequent work auxiliary materials	100.00	m			90.60			
Shotcrete material 2 x 50.00m tunnel x 50.2 m²/m, wet shotcrete 0.518 m³/m x 100.0m	51.80	m³			61.61			
Shotcrete material 2 x 50.00 m tunnel x 50.2 m²/m, Flowing concrete 4.140kg/m x 100.0 m	414.00	kg			0.95			
Shotcrete material 2 x 50.00 m tunnel x 50.2 m²/m, delvocrete 0.621 kg/m x 100.0 m	62.10	kg			2.08			
Shotcrete material 2 x 50.00 m tunnel x 50.2 m²/m, alkali-free accelerants 12.420 kg/m x 100.0 m	1242.00	kg			0.59			

Shotcrete power, electricity incl. lubricants 9.419 kWh / m² x 2,104.0 m²	19,817.58	kWh			0.10			
Shotcrete attrition, attrition of shotcrete parts	2,104.00	m²			3.17			
Disposal of rebound materials and shotcrete, Diesel and lubricants 0.108 l / m² x 2,104.0 m²	227.23	ltr			0.91			
Disposal of rebound materials and shotcrete, disposal 0.068 x 2,104.0 m²	143.07	m²			1.81			
Support arches 3.333 m / m x 100.0 m	333.30	m			1.81			
Support arches 2.333 m / m x 100.0 m	233.30	m			4.53			
Support arches 1.333 m / m x 100.0 m	133.30	m			30.80			
Support arches 0.410 t / m x 100.0 m	297.17	t			724.80			
Reinforcement Structural steel grid BSt M, without installation 0.263 t / m x 100.0 m	26.30	t			471.12			
Reinforced, auxiliary materials	1.00	-			4.53			
Water supply pipes DN80, water supply pipes	100.00	m			23.58			
Fixtures, suspensions etc., auxiliary materials	100.00	m			4.53			
Removal of walls to secondary tunnels, Diesel and lubricants 3.0 l / m³ x 938.0 m³	2,814.00	ltr			0.91			
Removal of walls to secondary tunnels, attrition	938.00	m³			2.27			
Removal of microtunnels, auxiliary materials	100.00	m			36.24			
Direct costs of partial services								
Unit costs			220,857.00	24,200.00	290,785.38	0.00	0.00	535,842.38 € / ea
Direct costs			220,857.00	24,200.00	290,785.38	0.00	0.00	535,842.38 €
Surcharge rates	in percent		12.00	12.00	12.00	12.00	12.00	
Surcharge			26,502.84	2,904.00	34,894.25	0.00	0.00	64,301.09 € / ea
Unit price	**600,143.47 € / ea**				**Total**			**600,143.47 €**

2.5.4 Example – Floating assembly

2.5.4.1 Performance description

The following example shows a tunnel for road traffic underpassing a river, which includes creation of two-way tunnel tubes, on the one hand, and facilitation of vehicle approach ramps, on the other. Figure 2.24 shows the horizontal tunnel section with the disposition of the tunnel elements. Total tunnel length amounts to roughly 790 m, and the tunnel consists of six individual tunnel segments. The entrance sites have a length of about 25 m at the east and 50 m at the west end, respectively.

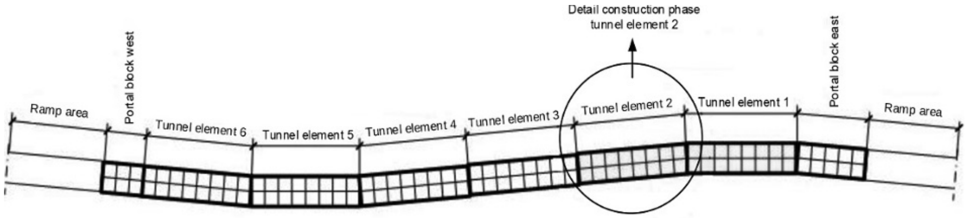

Figure 2.24 Floating assembly

The tunnel segments inside the river area are created employing the floating assembly or submersion method. The methods entail the prefabrication of the tunnel segments on land or in a dry dock with subsequent floating into position and submersion of the segments into the designated tunnel path. The six tunnel segments have an individual length of roughly 120 m and are manufactured of waterproof concrete in a dry dock. In order to minimize construction time, two tunnel segments are assembled simultaneously on separate construction lines (line 1 and line 2). A single tunnel segment, in this case, entails eight individual assembly stages. Tunnel segments 1 and 2 assembled during stage 1, hence, consist of eight individual sub-segments (SE1.1 to 1.8 and SE2.1 to 2.8).

Figure 2.25 shows a section of a tunnel segment. The tunnel tube is going to contain two separate two-lane roads divided by a wall in the tunnel center.

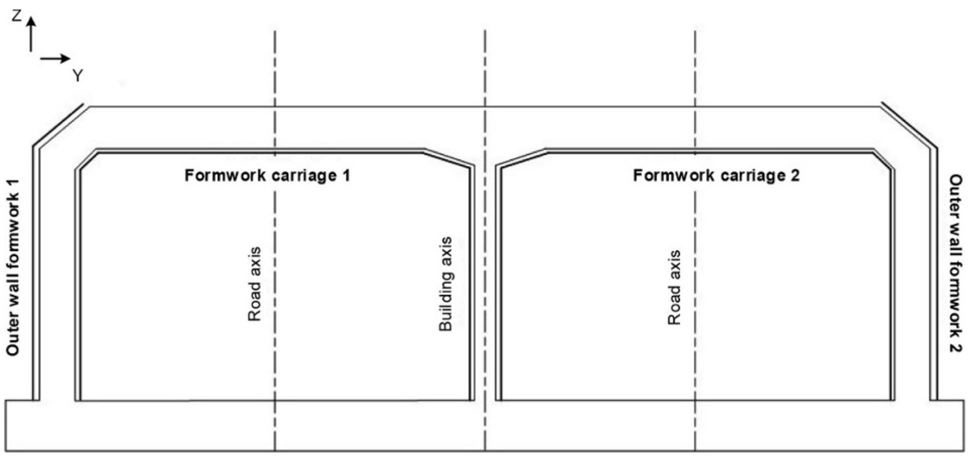

Figure 2.25 Section of a tunnel segment

Each end of the tunnel tubes is sealed or proofed with bulkhead partitions and, after the construction dock has been flooded, are floated into the river through a floodgate facility. Ballast tanks keep the sealed tunnel segments submerged as deeply as possible in order to increase their resistance to forces exerted by waves, wind etc. The individual assembled tunnel segments are stored in a temporary harbor in this state. Remaining water between the bulkheads is pumped out subsequently. Once tunnel segments form a completely sealed tunnel, the bulkheads are removed to allow inflow of air. During actual construction of the tunnel, individual segments are positioned on auxiliary foundations, pushed together via hydraulic presses and joined together.

Figure 2.26 Assembly of tunnel segments

The first construction stage entails assembly of tunnel segments 1 and 2. A channel for pipes and supply lines is created parallel to the construction stage of the last tunnel segments (TS 5 and TS 6), and submersion of temporarily stored segments begins. In conjunction with the monolithic entrance structures, total tunnel length amounts to 790 m. After completion of the tunnel, construction pits are removed and river banks restored.

Floating elements are manufactured of reinforced concrete, waterproof, and highly resilient against chemical corrosion. The tunnel floors, walls, and ceiling of each segment are created as a single body (meaning monolithic). In order to reduce cracking and ruptures of concrete in the areas where the tunnel segments are joined together, the construction times for both floors and ceilings have to be reduced as much as possible and must not exceed a period of five days. Jacketed or encapsulated pipes have to be sealed against hydraulic pressure. Concrete mixer vehicles are not permitted in the construction pit, except in emergencies.

2.5.4.2 Construction schedule

Rough schedule

Figure 2.27 shows an example of a construction schedule for a tunnel segment including the floating into position of the sub-segments. Moreover, the major processes in the schedule are described in detail in paragraphs that follow.

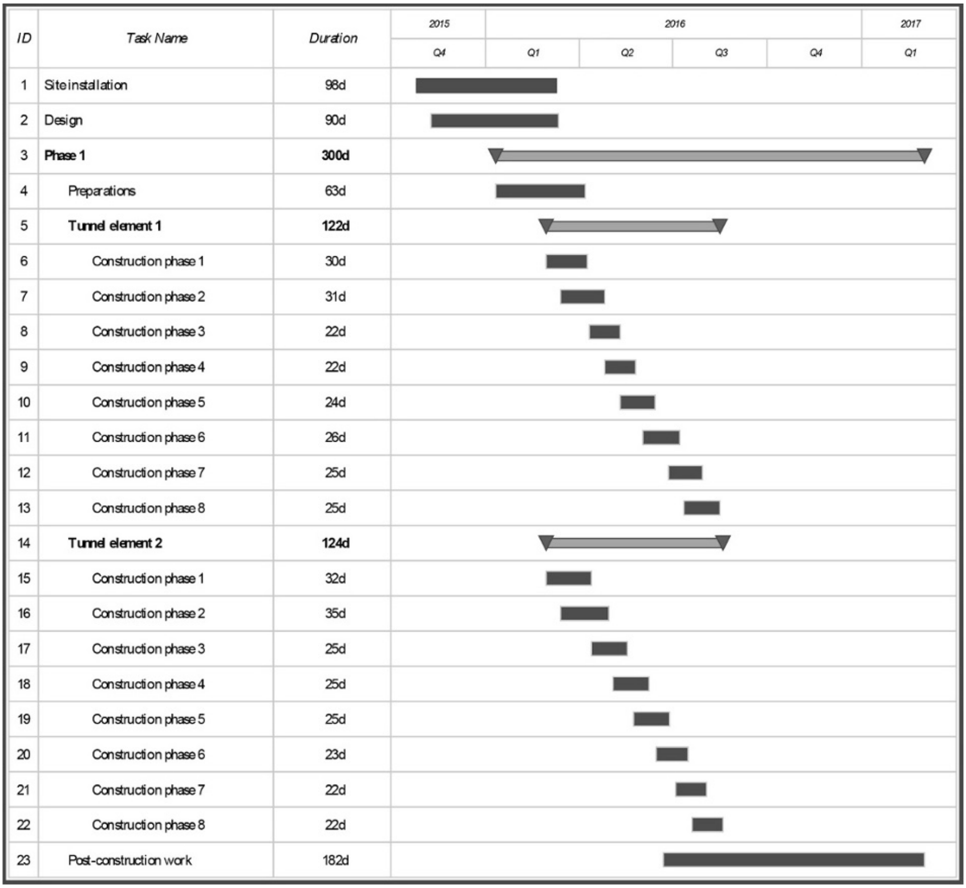

Figure 2.27 Schedule using the example of floating assembly

Construction site facilities

During the initial stage, the construction site facilities are erected together with a concrete mixing facility and subsequent installation of site offices and on-site laboratory.

ID	Task Name	Duration
1	**Building site facilities**	**98d**
2	Contract assignment	0d
3	Assembly of mixing facility	54d
4	Preparation of health and safety plan	6d
5	Assessment and approval of health and safety plan	10d
6	Installation of site office	2d
7	Creation of sample block	10d
8	Assembly of on-site laboratory	5d
9	Creation of above-ground storage areas	49d
10	Creation of crane runways for construction dock	10d
11	Assembly of cranes I + II	5d

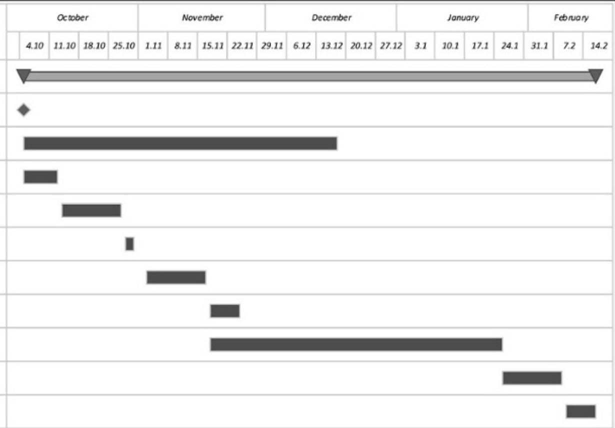

Figure 2.28 Schedule for the erection of construction site facilities

Construction cranes and concrete pumps are relocated via crane runways. Figure 2.29 shows the assembly of crane runways for two construction cranes and one master pump.

Figure 2.29 Crane runway

Design
During the scheduling stage, the contractor is required to calculate structural requirements for the concrete shells of the tunnel. The calculations are then reviewed and approved. Additional scheduling (total structural requirements, reinforcement calculations etc.) is realized by the client.

Pre-construction arrangements
During this stage, gravel bedding is created and formwork carriages for line I and line II assembled.

Construction stage one

ID	Task Name	Start	Finish	Duration
1	**Construction phase 1**	**11.01.2016**	**09.02.2016**	**22d**
2	Formwork floor 1.1	11.01.2016	20.01.2016	8d
3	Reinforcement floor 1.1	11.01.2016	20.01.2016	8d
4	Concrete floor 1.1	22.01.2016	22.01.2016	1d
5	Formwork carriage 1 in position	26.01.2016	26.01.2016	1d
6	Reinforced inner wall	27.01.2016	27.01.2016	1d
7	Reinforcement outer wall 1	27.01.2016	29.01.2016	3d
8	Reinforcement ceiling 1.1	27.01.2016	03.02.2016	6d
9	Formwork carriage 2 in position	28.01.2016	28.01.2016	1d
10	Reinforced outer wall 2	29.01.2016	02.02.2016	3d
11	Final inspection reinforcement outer wall 1	01.02.2016	01.02.2016	1d
12	Install outer wall formwork 1	02.02.2016	02.02.2016	1d
13	Final inspection reinforcement outer wall 2/ceiling	03.02.2016	03.02.2016	1d
14	Tie rod jacket tubes 1.1	03.02.2016	03.02.2016	1d
15	Install outer wall formwork 2	04.02.2016	04.02.2016	1d
16	Fitting of bulkhead formwork	04.02.2016	04.02.2016	1d
17	Concrete frame 1.1	08.02.2016	09.02.2016	2d

Figure 2.30 Schedule – Construction stage one

Post-construction

After the construction works with reinforced concrete are completed, ballast tanks are installed and bulkheads sealed. Positioning (i. e. floating) of segments begins after involved equipment and devices are secured and ballast tanks reviewed for waterproof capacity.

ID	Task Name	Duration
1	**Post-construction works**	**182d**
2	Installation of ballast tanks	71d
3	Bulkhead partitions, side 1	18d
4	Sealing	12d
5	Assembly of prefabricated segments	35d
6	Pre-stressing	8d
7	Expansion of formwork	10d
8	Hardware protection	24d
9	Waterproof test for ballast tanks	10d
10	Bulkhead partitions, side 2	12d
11	Buffer for accidents and downtimes	24d
12	Winter buffers	32d
13	Floating of elements	48d

Figure 2.31 Schedule – Post-construction phase

2.5.5 Costing and pricing

Table 2.46 shows the total calculated costs for the construction project. The calculation considers specific additional charges: A 12 % charge on manufacturing costs consisting of 9 % general overheads and 3 % profits. Site overheads were calculated directly. Furthermore, due to the difficulties involved with this project, present calculated risks are also taken into consideration.

Table 2.46 Itemization of total costs

Description	Calculated amount
Construction site creation	1,622,980.35 €
Constructions with (reinforced) concrete	8,530,975.21 €
Sealing	488,787.45 €
Design, preparations, drafting, consultations	71,648.43 €
Auxiliary construction work in tunnel segments	394,875.84 €
Construction dock operations after draining of construction site	28,140.00 €
Prestressing	415,935.00 €
Model segment	5,494.51 €
Railings	11,679.00 €
Sealing	18,114.80 €
Concrete delivery	3,223,005.73 €
Equipment assembly	24,131.88 €
Equipment disassembly	61,538.49 €
Total	**14,897,306.69 €**

The following paragraphs give a more detailed calculation process analysis for some items in the table.

2.5.5.1 Construction site facilities and overheads

Construction site facilities

This item includes one-time costs for the setup of the construction site facilities, assembly of cranes and site supply lines.

Not included in this item are availability costs for equipment as well as maintenance and operation costs of equipment and facilities (including rent and fees). Hence, this item does not contain time-dependent costs.

Table 2.47 Calculation of construction site facilities

Specifications			
Item	Qty.	Unit	Short description of operation
	1.00	ea	Construction site facilities

Unit costs								
Cost type	Qty.	Unit	Wage	Equip-ment	Material	Misc.	Third-party	
			€/h	€/unit	€/unit	€/unit	€/unit	
Preparation of site area	15,000.00	m²	1.25					
Creation of construction road	5,000.00	m²					5.10	
Ambulance service	3.00	ea				7,895.42		
Other transport costs	77.00	t	12.53			28.06		
Crane assembly	3.00	ea	2,539.02	357.14		5,170.07		
"Assembly of containers/ equipment"	20.00	ea	105.26	53.57				
Electricity supply	1.00	ea					4,336.73	
Initial installation of electricity lines	1.00	ea				2,551.02		
Water supply	1.00	ea				5,612.24		
Office equipment and container	1.00	ea				5,102.04		
Initial provision with small equipment/tools	1.00	ea				5,102.04		
Initial provision of consumable supplies	1.00	ea				5,102.04		
Direct costs of partial services								
Unit costs			29,437.07	2,142.82	0.00	64,826.47	29,836.73	126,243.09 €/ea
Direct costs			29,437.07	2,142.82	0.00	64,826.47	29,836.73	126,243.09 €
Surcharge rates	in percent		12.00	12.00	12.00	12.00	12.00	
Surcharge			3,532.45	257.14	0.00	7,779.18	3,580.41	15,149.18 €/ea
Unit price	**141,392.27 €/ea**				**Total**			**141,392.27 €**

Availability costs of equipment

The following itemization includes time-dependent costs only, i.e. costs accrued in order to ensure availability of cranes, containers, and small devices. A total construction time of 15 months - construction of six tunnel segments - is assumed for the calculation.

Table 2.48 Calculation of availability costs

Specifications			
Item	Qty.	Unit	Short description of operation
	1.00	ea	Equipment availability

Unit costs							
Cost type	Qty.	Unit	Wage €/mo.	Equipment €/unit	Material €/unit	Misc. €/unit	Third-party €/unit
Cranes for surface construction, 2 units	15.00	mo	8,017.96	15,466.33			
"Crane for surface construction SK 55, 1 unit"	10.00	mo	1,753.93	2,858.75			
Wheel loader, Kramer	10.00	mo		1,231.63			
VW transport	10.00	mo		536.73			

Surface vibrators, diverse models	16.00	mo		228.57				
Wastewater pumps, diverse models	16.00	mo		30.20				
Screw compressor with tubes	15.00	mo		572.65				
"Rock breaker HILTI TE 74"	15.00	mo		18.88				
Distribution cabinet, main distributor	15.00	mo		145.71				
Distribution cabinets, auxiliary distributors for diverse sites	15.00	mo		222.50				
Rental fees of third-party machinery	15.00	mo		2,551.02				
Container for site management personnel (combination of 3)	15.00	mo		1,215.82				
Accommodation container, 6 units for 6 employees each	15.00	mo		925.71				
W/T Container, 2 units for 6 empl. each	15.00	mo		554.04				
Warehouse container, 3 units for 6 employees each	15.00	mo		161.36				
Rental fees for office supplies, fax and copy machine	15.00	mo		204.08				
Theodolite, 2 units	15.00	mo		119.43				
Automatic surveyor's optical level, 2 units	15.00	mo		57.72				
"Mobile telephones, 2 units"	15.00	mo		175.03				
Circular saws ZBV 600, 4 units	15.00	mo		144.31				
Converter and vibration bottles	15.00	mo		355.67				
Concrete bucket 750l	15.00	mo		28.38				
Other construction equipment	15.00	mo		510.20				
Electricity incl. consumption	15.00	mo		755.10				
Water consumption	15.00	mo		1,077.55				
Truck-mounted crane	300.00	h		67.35				
Small equipment and tools	15.00	mo		637.76				
Waste container skeleton	15.00	mo					1,724.49	
Direct costs of partial activities								
Unit costs			137,808.70	459,105.17	0.00	0.00	25,867.35	622,781.22 €/ea
Direct costs			137,808.70	459,105.17	0.00	0.00	25,867.35	622,781.22 €
Surcharge rates	in percent		12.00	12.00	12.00	12.00	12.00	
Surcharge			16,537.04	55,092.62	0.00	0.00	3,104.08	74,733.74 €/ea
Unit price	**697,514.98 €/ea**				**Total**			**697,514.96 €**

Construction site clearing

This item includes costs resulting from removal, disassembly, and transport of employed equipment and facilities. Areas and paths, which had come under use during construction, are restored in accordance with their aesthetic and ecological requirements. Hence, this item also does not contain time-dependent costs.

Table 2.49 Calculation of construction site clearing costs

Specifications			
Item	Qty.	Unit	Short description of operation
	1.00	ea	Site clearance

Unit costs								
Cost type	Qty.	Unit	Wage €/unit	Equip-ment €/unit	Material €/unit	Misc. €/unit	Third-party €/unit	
Land restoration incl. construction road	5,000.00	m²					4.08	
Crane transportation	3.00	ea	2,643.42			5,920.92		
Other disassembly costs	77.00	t	12.53			28.06		
Crane disassembly	3.00	ea	1,904.27	2,525.51		3,877.55		
Disassembly of equipment and containers	20.00	ea	101.24	51.02				
Direct costs of partial services								
Unit costs			16,632.68	8,596.93	0.00	31,556.03	20,400.00	77,185.64 €/ea
Direct costs			16,632.68	8,596.93	0.00	31,556.03	20,400.00	77,185.64 €
Surcharge rates		in percent	12.00	12.00	12.00	12.00	12.00	
Surcharge			1,995.92	1,031.63	0.00	3,786.72	2,448.00	9,262.28 €/ea
Unit price		**86,447.92 €/ea**			**Total**			**86,447.92 €**

Construction site overheads

The following item includes construction site overhead costs in conjunction with construction time. For the calculation, it is assumed that a construction site manager and foreman are employed for a period of twenty months, which includes respective pre-construction and post-construction periods for scheduling and project finalization.

Table 2.50 Calculation of time variable site overheads

Specifications			
Item	Qty.	Unit	Short description of operation
	1.00	ea	Time variable site overheads

Unit costs							
Cost type	Qty.	Unit	Wage €/h	Equip-ment €/unit	Material €/unit	Misc. €/unit	Third-party €/unit
Site manager	20.00	mo				5,867.35	
Planning engineer	3.00	mo				5,102.04	
Management assistant	5.00	mo				3,826.53	
First foreman	20.00	mo				5,255.10	
Site transportation, intermediate storage	15.00	mo	2,004.39				
Removal of surface water	15.00	mo	250.56				
Surveying help	15.00	mo	501.12				
Permanent site security	15.00	mo	439.90				
Other indirect labor costs	15.00	mo	2,505.61				
Site lighting	1.00	ea				2,551.02	
Formwork, covering, protectors	1.00	ea				25,510.20	

"Office cleaning, cleaning W/T- Container"	15.00	mo				561.22		
Office costs, telephone, food services	15.00	mo				510.20		
Blueprints	15.00	mo				1,020.41		
Construction site insurance	1.00	ea				22,397.96		
Direct costs of partial services								
Unit costs			85,523.70	0.00	0.00	338,724.40	0.00	424,248.10 €/ea
Direct costs			85,523.70	0.00	0.00	338,724.40	0.00	424,248.10 €
Surcharge rates		in percent	12.00	12.00	12.00	12.00	12.00	
Surcharge			10,262.84	0.00	0.00	40,646.93	0.00	50,909.77 €/ea
Unit price		**475,157.87 €/ea**			**Total**			**475,157.87 €**

2.5.5.2 Floating elements

Gravel materials

This item includes delivery of required gravel materials as well as integration, compression, and sealing into the construction dock floor. Requirements to repair imperfections of the construction dock floor should be taken into consideration. Reliability and operability of site filtration wells have to be ensured.

Table 2.51 Calculation of gravel material

Specifications								
Item	Qty.	Unit	Short description of operation					
	5,600.00	m³	Supply and integration of gravel materials					
Unit costs								
Cost type	Qty.	Unit	Wage €/m³	Equip-ment €/m³	Material €/m³	Misc. €/m³	Third-party €/m³	
Gravel material supply	1.00	m³					25.50	
Direct costs of partial services								
Unit costs			0.00	0.00	0.00	0.00	25.50	25.50 €/m³
Direct costs			0.00	0.00	0.00	0.00	142,800.00	142,800.00 €
Surcharge rates		in percent	12.00	12.00	12.00	12.00	12.00	
Surcharge			0.00	0.00	0.00	0.00	17,136.00	17,136.00 €
Unit price		**28.56 €/m³**			**Total**			**159,936.00 €**

Formwork material

The following item includes calculations for delivery of composite lumber as selected by the contractor. Composite lumber is installed in previously created areas according to tunnel profile. The panels are fixed onto the concrete with barbed nails.

Table 2.52 Calculation of formwork

Specifications			
Item	Qty.	Unit	Short description of operation
	16,100.00	m²	Installation of composite lumber as formwork

Unit costs								
Cost type	Qty,	Unit	Wage €/m²	Equip-ment €/m²	Material €/m²	Misc. €/m²	Third-party €/m²	
Install particle board as formwork	1.00	m²						
Wages (assembly parts) 1.00 m²/m² x 0.10 h/m² x 25.06 €/h	0.10	h/m²	2.51					
Oriented structural boards 18 mm 1.1 m²/m² x 1.0 m² x 6.58 €/m²	1.00	m²			7.24			
Other construction materials 1.0 m²/m² x 1.0 m²/m² x 1.50 €/m²	1.00	m²			1.50			
Install barbed nails	1.00	m²						
Wages (assembly parts) 0.05 h/m² x 1.00 m²/m² x 25.06 €/h	0.05	h/m²	1.25					
Construction materials 1.00 m²/m² x 1.00 m²/m² x 0.51 €/m²	1.00	m²			0.51			
Install rinsing openings	102	ea						
Wages (assembly parts) 1.00 h/pc x 102 pc/16,100m² x 25.06 €/h	1.00	h/ea	0.16					
Recesses for hydraulic presses	6.00	ea						
Wages (assembly parts) 1.00 h/pc x (6pc/16,100m²) x 25.06 €/h	1.00	h/ea	0.01					
Direct costs of partial services								
Unit costs			3.93	0.00	9.25	0.00	0.00	13.18 €/m²
Direct costs			63,273.00	0.00	148,925.00	0.00	0.00	212,198.00 €
Surcharge rates		in percent	12.00	12.00	12.00	12.00	12.00	
Surcharge			7,592.76	0.00	17,871.00	0.00	0.00	25,463.76 €
Unit price		**14.76 €/m²**			**Total**			**237,661.76 €**

Creation of floor slabs

This item includes assembly, availability, and disassembly of formwork in accordance with provided design and construction documents. Moreover, integration of reinforcement structures and concrete have to be taken into consideration.

Table 2.53 Calculation of floor slabs

Specifications								
Item	Qty.	Unit	Short description of operation					
	20,000.00	m³	Production of reinforced concrete including formwork					
Unit costs								
Cost type	Qty.	Unit	Wage €/m³	Equipment €/m³	Material €/m³	Misc. €/m³	Third-party €/m³	
Production and installation of C30/37 WU	1.00	m³						
B35 WU I + A KR32 1.00 m³/m³ x 1 m³/m³ x 75.51 €/m³"	0.01	m³/m³			75.51			
Wages (concrete) 0.30 h/m³ x 1.00 m³/m³ x 25.06 €/h	0.30	h/m³	7.52					
Formwork	3,440.00	m²						
Wages (formwork) 0.80 h/m² x (3,440 m²/20,000 m³) x 25.06 €/h	0.80	h/m²	3.45					
System formwork 1.00 m²/m² x (3,440m²/20,000 m³) x 10.66 €/h	1.00	m²/m²			1.83			
Abrading and deburring	16,154.00	m²						
Wages (concrete) 0.11 h/m³ x (16,154 m²/20,000 m³) x 25.06 €/h	0.11	h/m²	2.23					
Purchase of formwork	1.00	ea						
System formwork 1.00 x (1/20,000 m³) x 7,653.06 €	1.00	ea			0.38			
Direct costs of partial services								
Unit costs			13.20	0.00	77.72	0.00	0.00	90.92 €/m³
Direct costs			264,000.00	0.00	1,554,400.00	0.00	0.00	1,818,400.00 €
Surcharge rates		in percent	12.00	12.00	12.00	12.00	12.00	
Surcharge			31,680.00	0.00	186,528.00	0.00	0.00	218,208.00 €
Unit price		**101.83 €/m³**			**Total**			**2,036,608.00 €**

Creation of outside tunnel walls

Table 2.54 Calculation of outside tunnel walls

Specifications			
Item	Qty.	Unit	Short description of operation
	8,000.00	m³	Production of reinforced concrete including formwork

Cost type	Qty.	Unit	Wage €/m³	Equip-ment €/m³	Material €/m³	Misc. €/m³	Third-party €/m³	
Unit costs								
Production and installation of C 30/37 WU	1.00	m³						
C 30/37 WU I + A KR32 1.00 m³/m³ x 1.00m³/m³ x 75.51€/m³	1.00	m³			75.51			
Wages (concrete) 0.35 h/m³ x 1.00 m³/m³ x 25.06 €/h	0.35	h/m³	8.77					
Formwork	21,130.00	m²						
Wages (formwork) 0.82 h/m² x (21,300 m²/8,000 m³) x 25.06 €/h	0.82	h/m²	54.28					
System formwork 1.00 m²/m² x (21,300 m²/8,000 m³) x 7.70€/m²	1.00	m²			20.50			
Recesses	7.00	m²						
Wages (formwork) 1.80 h/m² x (7.0m²/8,000 m³) x 25.06 €/h	1.80	h/m²	0.04					
System formwork 1.00 m²/m² x (7.0 m²/8,000 m³) x 7.65 €/m²	1.00	m²			0.01			
Shorings	1.00	m²						
Protective structures and scaffolding 1.00 m²/m² x 1.0 m²/m³ x 5.10 €/m²	1.00	m²					5.10	
Purchase of formwork	1.00	ea						
System formwork 1.0 x (1/8,000 m³) x 22,448.98 €/pc	1.00	ea				2.81		
Direct costs of partial services								
Unit costs			63.09	0.00	96.02	2.81	5.10	167.02 €/m³
Direct costs			504,720.00	0.00	768,160.00	22,480.00	40,800.00	1,336,160.00 €
Surcharge rates	in percent		12.00	12.00	12.00	12.00	12.00	
Surcharge			60,566.40	0.00	92,179.20	2,697.60	4,896.00	160,339.20 €/m³
Unit price	**187.06 €/m³**				**Total**			**1,496,499.20 €**

Creation of inner tunnel walls

Table 2.55 Calculation of inner tunnel walls

Specifications								
Item	Qty.	Unit	Short description of operation					
	2,400.00	m^3	Production of reinforced concrete including formwork					
Unit costs								
Cost type	Qty.	Unit	Wage €/m^3	Equipment €/m^3	Material €/m^3	Misc. €/m^3	Third-party €/m^3	
Production and installation of B35 WU	1.00	m^3						
B35 WU I + A KR32 1.00 m^3/m^3 x 1.00 m^3/m^3 x 75.51 €/m^3	1.00	m^3			75.51			
Wages (concrete) 0.35 h/m^3 x 1.00 m^3/m^3 x 25.06 €/h	0.35	h/m^3	8.77					
Formwork	10,630.00	m^2						
Wages (formwork) 0.82 h/m^2 x (10,630 m^2/ 2,400 m^3) x 25.06 €/h	0.82	h/m^2	91.02					
System formwork 1.00 m^2/m^2 x (10,630 m^2/ 2,400 m^3) x 7.70 €/m^2	1.00	m^2			34,1			
Recesses	7.00	m^2						
Wages (formwork) 1.80 h/m^2 x (5.0 m^2/2,400 m^3) x 25.06 €/h	1.80	h/m^2	0.09					
System formwork 1.00 m^2/m^2 x (5.0 m^2/ 2,400 m^3) x 7.65 €/m^2	1.00	m^2			0.02			
Shorings	1.00	m^2						
Protective structures and scaffolding (included in outer wall)								
Purchase of formwork	1.00	ea						
System formwork 1.0 x (1/2,400 m^3) x 14,000 €/pc	1.00	ea				5.83		
Direct costs of partial services								
Unit costs			99.88	0.00	109.63	5.83	0.00	215.34 €/m^3
Direct costs			239,712.00	0.00	263,112.00	13,992.00	0.00	516,816.00 €
Surcharge rates		in percent	12.00	12.00	12.00	12.00	12.00	
Surcharge			28,765.44	0.00	31,573.44	1,679.04	0.00	62,017.92 €/m^3
Unit price		**241.18 €/m^3**			**Total**			**578,833.92 €**

Creation of tunnel ceiling

Table 2.56 Calculation of tunnel ceiling

Specifications								
Item	Qty.	Unit	Short description of operation					
	16,000.00	m³	Production of reinforced concrete including formwork					
Unit costs								
Cost type	Qty.	Unit	Wage €/unit	Equip-ment €/unit	Material €/unit	Misc. €/unit	Third-party €/unit	
Production and installation of B 35 WU	1.00	m³						
B35 WU I + A KR32	1.00	m³			75.51			
Wage (concrete) average wage = 25.06 €/h	0.35	h/m³	8.77					
Formwork	11,010.00	m²						
Wages (formwork) 0.82 h/m² x (10,630 m²/2,400 m³) x 25.06 €/h	0.82	h/m²	14.14					
System formwork 1.00 m²/m² x (10,630 m²/ 2,400 m³) x 7.70 €/m²	1.00	m²			5.30			
Extra pay reinforcement construction	1,400.00	m²						
Average wage = 25.06 €/h 0.70 h/m² x (1,400 m²/ 16,000 m³)	0.06	h/m³	1.53					
Abrading and deburring	14,500.00	m²						
Average wage = 25.06 €/h 0.10 h/m² x (14,500 m²/ 16,000 m³)	0.09	h/m³	2.27					
Recesses	18.00	m²						
System formwork 18 m²/16,000 m³ x 7.70 €/m²	0,001	m²/m³			0.01			
Average wage = 25.06 €/h 1.8 h/m² x (18 m²/16,000m³)	0,002	h/m³	0.05					
Purchase of formwork	1.00	ea						
System formwork 47,500 € fixed	1.00	ea				2.97		
Direct costs of partial services								
Unit costs			26.76	0.00	80.82	2.97	0.00	110.55 €/m³
Direct costs			428,160.00	0.00	1,293,120.00	47,500.00	0.00	1,768,780.00 €
Surcharge rates		in percent	12.00	12.00	12.00	12.00	12.00	
Surcharge			51,379.20	0.00	155,174.40	5,700.00	0.00	212,253.60 €/m³
Unit price		**123.81 €/m³**			**Total**			**1,981,033.60 €**

Creation of rebar

This item includes delivery and integration of rebar and rebar mats in accordance with structural and construction requirements.

Table 2.57 Calculation of rebar

Specifications			
Item	Qty.	Unit	Short description of operation
	6,866.00	t	Delivery and installation of rebar

Unit costs								
Cost type	Qty.	Unit	Wage €/unit	Equip-ment €/unit	Material €/unit	Misc. €/unit	Third-party €/unit	
Rebar BSt 500 S	6,500.00	t						
440 €/t acc. to price inquiry with the supplier	94,6694	%					416.55	
Rebar mats BSt 500 M	366.00	t						
480 €/t acc. to price inquiry with the supplier	5,3306	%					25.59	
Direct costs of partial services								
Unit costs			0.00	0.00	0.00	0.00	442.13	442.13 €/m³
Direct costs			0.00	0.00	0.00	0.00	3,035,664.58	3,035,664.58 €
Surcharge rates		in percent	12.00	12.00	12.00	12.00	12.00	
Surcharge			0.00	0.00	0.00	0.00	364,279.75	364,279.75 €/m³
Unit price	**495.19 €/m³**				**Total**			**3,399,944.33 €**

Creation of ballast tanks

This item includes the manufacturing of ballast tanks for the total of six submersion elements including delivery of required materials. The review of waterproof capacity is included in the price. Filling of ballast tanks for the purpose of submerging tunnel segments is not included in the calculation.

Table 2.58 Calculation of ballast tanks

Specifications			
Item	Qty.	Unit	Short description of operation
	6.00	ea	Installation of ballast tanks

Unit costs							
Cost type	Qty.	Unit	Wage €/unit	Equipment €/unit	Material €/unit	Misc. €/unit	Third-party €/unit
Section steel	14.00	t					
1,600 €/to acc. to price inquiry with the supplier	2.33	t/ea					3,733.33
Install poling boards between supports	51.00	m³/ea					
Scantling 8 x 12 cm/160 €/m³	51.00	m³/ea			8,160.00		
Average wage = 25.06 €/h 4.1 h/m³ x 51 m³/pc	209.10	h/ea	5,240.05				
Sealing film	1,250.00	m²/ea					
Average wage = 25.06 €/h 0.25 h/m² x 1,250 m²/pc	312.50	h/ea	7,831.25				
Material = 8.22 €/m²	1,250.00	m²/ea			10,275.00		
Specialized scaffolding		ea		14,435.00			
Direct costs of partial services							

Unit costs		13,071.30	14,435.00	18,435.00	0.00	3,733.33	49,674.63	€/ea
Direct costs		78,427.80	86,610.00	110,610.00	0.00	22,399.98	298,047.78	€
Surcharge rates	in percent	12.00	12.00	12.00	12.00	12.00		
Surcharge		9,411.34	10,393.20	13,273.20	0.00	2,688.00	35,765.73	€/ea
Unit price	**55,635.59 €/ea**			**Total**			**333,813.51**	**€**

2.6 Estimating of foundation engineering works

2.6.1 Basics

A cost estimate in the field of special foundation engineering works cannot be compared to the process of calculating prices for industrial goods. The presence of various weather and soil conditions makes general comparison methods increasingly difficult.

As a result of the particularities involved in special foundation engineering projects, an individual calculation has to be performed for each project.

Determining the exact construction cost values is achieved through a systematic calculation procedure, and all relevant costs incurred during project realization (wages, equipment, materials, subcontractor activities, construction management, site preparation, overhead, and other costs) must be taken into account.

All works to be carried out should be clearly described, so any contractors reading the specifications have the same understanding of the description in order to perform the required cost estimate. First, the estimator has to arrange any cost factors that could influence the bid price. The required values are obtained from the following documents and information:

- Performance description
- On-site conditions
- Operational requirements (wages, equipment costs, general overheads, etc.)
- Performance requirements (experience with similar sites)
- Material costs (concrete, diesel, etc.)
- Additional costs (subcontractor, construction during winter months, etc.)

Hence, communication between the engineer, site manager, estimators, and contracting parties plays an important role. The following questions pertaining to conditions that influence the project are essential for the decision to run a pre-estimate:

- What size is the project (construction period, contract dates, available equipment, and staff, etc.)?
- Are activities listed in the contract included in the portfolio of the construction firm?
- What is the effect of the project on the workload of the company?
- Who is the client and how many bidders are likely to participate?

Management of risks and opportunities
Today, the decision to proceed with pre-contract calculations is connected to a functioning risk-reward management system. Without risk, there is no progress. However, some setbacks can easily be avoided when the risks are identified on time.

In general, construction engineering and special foundation engineering projects boast many risks due to the fact that every project is unique. Particularly, soil as foundation element can never be fully definable. The sensible management of risk requires special knowledge of this area fraught with imperfection.

Risk, within the boundaries of the management system, means any hazards which could affect the company in terms of reputation, integrity, quality, technical expertise, economic strength, safety, and ecological conduct. Individual management personnel have to be fully aware that risks can also offer opportunity.

Individual risks can be divided into the following groups:

– Product / market
– Ground conditions
– Financial
– Risks due to specific present environment,
– Employee
– Partners
– Contractual
– Performance
– Environmental
– EDP-related (e. g. construction engineering software)

Using the list above, both calculation parameters and recurring risks can be identified, monitored, and thus damage can be avoided during every phase of processing and updating of relevant items.

Estimating approach
To approach the estimation, information gained during project preparation are required and include adoptable construction methods and results derived from site analyses (soil analysis, in particular). Hence, contractual documents have to be thoroughly reviewed. Moreover, a preliminary structural analysis is often conducted.

During the process of calculating for special foundation engineering projects, individual solution proposals play an important role, and acquisition of profitable contracts is mostly impossible without them due to the highly competitive environment of the construction engineering market. Thus, a company that comes equipped with individual solutions to engineering tasks demonstrates not only a high level of competence in its special field but also gains an edge over its competitors. A company-owned technical department can intervene during the early stages of the design process. The aim is to deliver both, optimal solutions for the client and profitable solutions for the company. For example, major construction projects involving large pile foundations can be accompanied by pile tests (because of progressive development at manageable costs) to optimize pile size. Finally, total costs that fall under the responsibility of the construction company within the framework of unit-price contracts or enable the calculation of an attractive bid should be optimized in accordance with present market conditions.

A detailed estimation is important for preparing offers for special foundation engineering projects. Thus, negotiations with potential clients stand on a clear basis, and propositions to change contractual items can be reviewed towards their effects on the bid. Usually, an all-in-one solution is sought after enabling the respective company to build the entire construction site as the system provider.

After project conditions have been reviewed, other considerations have to be taken into account. Due to the complexity of engineering projects, forming a bidding consortium is a topical issue worth contemplation. This is the case if either company-owned human and equipment resources are too limited with respect to the project or the ratio of third-party works (e. g. 50 % construction site earthworks and demolition works, installation of support walls for flood protection, railroad construction) that are not part of the portfolio of a special foundation engineering company.

A site inspection has to be carried out prior to initiating the calculation process. The experiences of construction managers and planning engineers are essential in this respect. When bidding for public bids, any possible queries need to be clarified before submitting a bid. If the contracting party is a non-public client, conditions can be detailed in a proposal cover letter and defined as contractual prerequisites.

Estimating methods
Once estimating prerequisites have been largely resolved, the actual calculations begin, which are usually performed with the aid of computer-aided estimating programs and also due to the increasingly prevalent requirement to submit contract and bid documents electronically (PDF or CAD plans, specifications, information exchange).

The calculation is carried out using various techniques (e. g. cost-plus calculation) which can be performed with the help of EDP software or predefined equipment databases.

The following section focuses on calculation processes employing cost-plus pricing methods and predefined equipment databases. General overheads result from planned index figures of the accounting department. General overheads and site overhead costs are not generally distinguished hereinafter.

2.6.2 Costing and pricing

The cost components involved in the calculation are usually arranged as follows:

- Wage costs
- Material costs
- Equipment costs
- Miscellaneous costs
- Subcontractor work

Special foundation engineering companies generally subdivide the items above into cost sub-groups such as transportation, rental costs for company-owned or third-party equipment, etc.

Wage costs are the result of calculated company wages computed through average wage, ancillary wage costs, fixed and union-rate social costs.

Material costs entail construction materials (concrete, cement, reinforcement steel, etc.), secondary materials (rental costs for piles and cantilevered steel, etc.) and consumables (diesel, lubricants, electricity, etc.).

Equipment costs are generally determined through a respective register of construction equipment (German register of construction equipment, 2015 edition) which organizes equipment items according to:

– Value as new
– Operating life
– Availability months
– Monthly depreciation and interest rates
– Monthly maintenance rate

However, it should be reviewed to what extent data taken from the register of construction equipment has to be adjusted according to company and project requirements. More accurate values can be fed into the calculation in cases where the company manufactures its own equipment (e. g. BAUER AG). It is not strictly necessary to use list prices as stated in the register. Rather, actual costs can be used, thus also considering the intensive utilization of construction equipment.

Miscellaneous costs are not directly allocated to any of the other four cost categories and have to be itemized separately when bidding for public contracts.

Subcontractor works include costs for services rendered by third parties for the construction project.

2.6.3 Examples

Creating the calculations for the following examples (pile foundation, soldier pile wall, sheet piling, and diaphragm wall) additional contractual conditions need to be considered (excerpts from the construction description):

1. The quantities listed in the bill of quantities are provided for calculation purposes only and have to be reviewed by the bidder to ensure accuracy and completeness.
2. The bidder is to review contracted performance requirements employing the full extent of their expertise and express reservations about specified materials, construction methods, etc. in writing when submitting their bid.
3. Brand, type, and technical details of equipment are to be specified if required by the bill of quantities. Alternatives are to be itemized accordingly with their rates. They must not be included in the total price. Any further desired changes have to be submitted separately.
4. The contractor handles any notifications issued by the construction control authority and is responsible for the immediate correction of complaint sources. Costs are reimbursed using going rates.
5. Post-construction works are to be carried out professionally and need to be considered in the total price.

6. The bidder is committed to review the construction site before submitting their bid. Any potential identified obstructions on-site are to be itemized accordingly or as extra items.
7. Contracts are awarded according to client's choice as lump-sum contracts or documented proof of performance (unit-price contract).
8. Prices specified in the bill of quantities apply to timely and complete construction work including supply of all materials, transport, and installation as well as all required special and ancillary activities. Costs for any site facilities are included.
9. The bidder appoints a qualified construction manager to supervise project realization on-site and ensure compliance with all health and safety regulations.
10. Electricity, water costs, and fees incurred for general insurance and construction site facilities are distributed evenly among departments involved in the construction project.
11. The contractor is responsible for daily waste disposal, particularly packaging materials, recycled materials, and special waste generated by construction activities in adherence with the currently applying disposal regulations. Costs incurred for general debris containers are reimbursed proportionally.
12. The contractor has to verify the correctness of preliminary works that have to be performed before project launch and, in a timely fashion, submit potential concerns in writing.
13. An appropriate contractual penalty is agreed between client and contractor.
14. Warranties are in effect in accordance with the respective contractual regulations for construction work with the guarantee extended to a period of five years beginning with acceptance of the completed construction by the client though no later than six months after acceptance between contractor and client.
15. The security deposit amounts to 5 % of the final bill over the period of guarantee obligation and may be redeemed through a letter of credit.
16. Contractual basis for non-specified conditions is defined by the latest edition of VOB Part B or respective contractual regulations for construction work outside Germany.

Particularly, requirements described in articles 1 (quantities for calculation purposes only), 4 (contractor handles notifications issued by construction control authority), 6 (itemization of existing obstructions), 8 (contractual prices apply to any required activities), and 10 (cost of general site facilities distributed evenly) have to be taken into account when preparing the submission of a bid. The obligation to include any necessary activities in the bid is of particular importance.

The bill of quantities includes additional requirements for rendered activities, which have to be included in the calculation. The bill consists of two main parts, one of which is the section concerned with pile foundation and the other pit lining. The introduction to the "Pile Foundation" section reads as follows: Activities require installation of pile foundations with a load-bearing capacity of ≥ 900 kN in order to absorb loads from the grillage foundation. The geological survey is available. Calibration of starting points, cutting to length of piles and any associated work, transport and disposal of borehole cuttings, and securing the construction site have to be considered for the calculation.

Particular attention should be paid to actually including any required activities described in the “Pit lining” section in the calculation.

Table 2.59 Bill of quantities of foundation engineering works

Item	Text	Qty.	Unit	Unit price (EUR/Qty.)	Total (EUR)
	Title 1: Pile Foundation				
1.1	Installation and clearing of construction site in order to perform following special foundation work. Rate includes following activities: – Transport/delivery of required equipment, equipment, transport vehicles, etc. – Assembly/disassembly of required equipment, equipment, transport vehicles, etc. – Resources, including project staff, for uninterrupted operation of rotary boring rig	1	ea		
1.2	Creation of verifiable structural engineering calculation and plan of realization (five copies) for offered activities in conjunction with following specifications: – Relevant reaction forces on top edge of pile, load-bearing data per pile – Calculation criteria and geological survey – Cross-sectional view of top edge of bored pile including reference points to geological survey and planned construction – Site layout including elevation values	1	ea		

1.3	Manufacture of in-situ large bored concrete piles with diameter of 880 mm acc. DIN 4014 and DIN EN 1536, respectively, incl. following partial activities: – Sinking of piles into soil acc. survey – Create empty bores – Delivery and integration of pile concrete C25/30, XC4, XF1, XA1 – Disposal of borehole cuttings – Pile length of 8.00 to 11.00 m; performance is billed per meter of pile measured from target top edge of pile and structure connected to bottom edge, respectively, to bottom edge of actual bored depth acc. manufacturer specifications	750	m		
1.4	– Delivery and installation of pile reinforcement; inclcluding the following activities: – Delivery of reinforcement cages consisting of BSt 500 S for structural and constructional reinforcement – Installation of cages into bores; – performance of reinforcement cages incl. required materials such as flat steel, x-bases, support rings, spacers, etc. billed acc. steel schedules	10	t		
1.5	Creation of in-situ concrete pile tops for addition of pile top plate and structure connected to pile, respectively; including the following partial activities: – Cuttings/exc. mat. transferred to ownership of contractor and disposed – Pile diameter maximum of 880 mm – height tolerance +/- 3 cm – billed per piece of chipped off bored pile top	1	ea		

1.6	Optional item: Add. person hours for removal of boring obstructions. Debris disposed by construction staff.	5	h		
	Total Section 1				
	Title 2: Pit-lining Work				
2.1	Delivery and creation of soldier pile pit linings (construction depth up to 5.30 m [visible area]). Ensure availability of linings incl. required bracings and anchors with subsequent removal after work completion. Structural engineering calculations provided by client. Installation to proceed in consultation with construction site management.	700	m^2		
2.2	Delivery and creation of permanent, watertight sheet tile wall (construction depth up to 5.30 m) incl. required anchors.	1,200	m^2		
	Title 2				

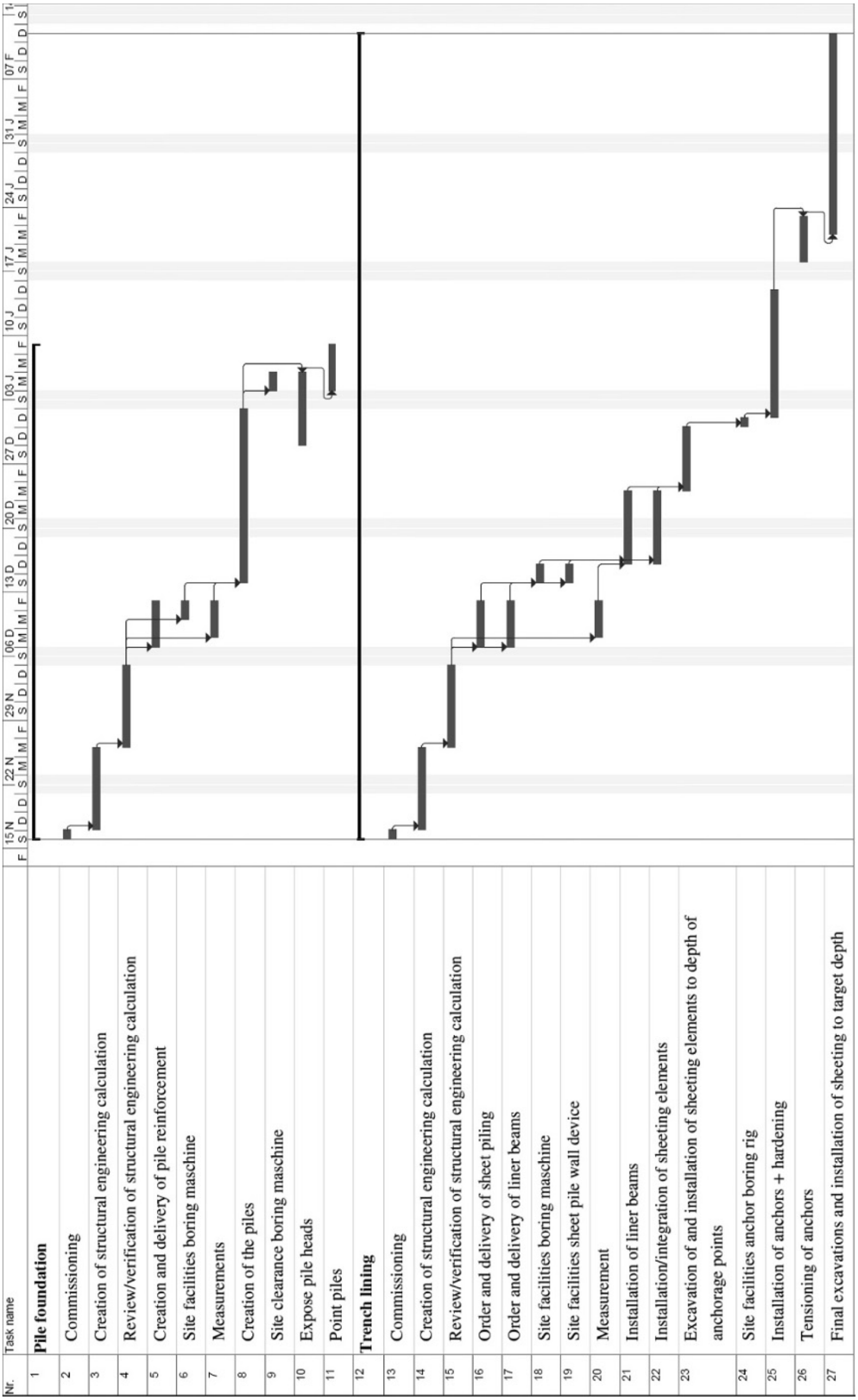

Figure 2.32 Construction schedule foundation engineering

2.6.3.1 Pile Foundation

A boring machine of the type BG 15H with equipment carrier BT 35, and telescopic carriage B 5 is employed for boring works. The machine is a rotary boring rig for diameters of up to 1,200 mm (cased) and depths up to 18 m and is primarily used to create pile and soldier pile bores as well as bored pile walls. Rental costs amount to approximately 60 to 70 % of prices listed in the register of construction equipment. Hence, the following examples assume rental costs of 70 % of listed prices for calculation purposes.

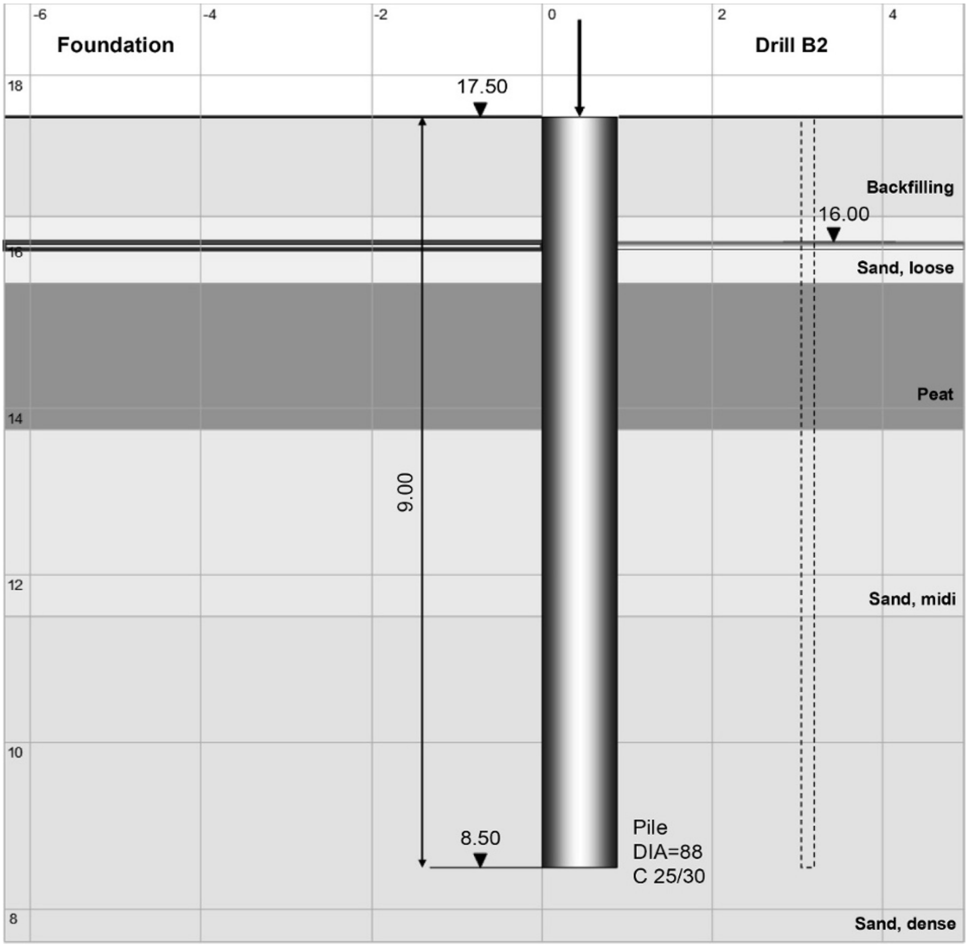

Figure 2.33 Bored pile foundation

First, costs for one working unit (large boring equipment and staff), including required construction site facilities, are determined for one workday (WD):

Boring unit
Equipment: BG 15, cased Kelly boring, 880 mm in diameter

Staff: 3 employees at 50.00 EUR/h

Working hours: 10 h/WD

Installed capacity: 155 kW

Rate of utilization: 0.70 (70 percent) of workday

Diesel: 1.20 EUR/l

Operating fluids consumption: 0.263 l/kWh

Costs			**EUR/WD**
Staff		10 h/WD x 3 x 50.00 €/h	1,500.00 €
Basic eqpt. BG 15		BAG BT 35 (155 kW)	2,137.47 €
Rot. top drive			203.38 €
Kelly L: 18 m			210.35 €
Wheel loader 40 – 52 kW			249.35 €
Container		workshop container 3 m	7.78 €
		accommodation container 3m	10.25 €
		sanitary container	10.25€
Operating fluids (main equipment and wheel loader)		195kW x 0.7 x 10h/WD x 0.2631/kW/h x 1.20 €/l	430.79 €
Rotary head			148.40 €
Casings	880/1 m	2 x 16.71 €	33.42 €
	880/2 m	4 x 18.45 €	73.80 €
	880/3 m	2 x 21.13 €	42.26 €
Casing shoes		2 x 39.00 €	78.00 €
Tools	Augers	2 x 29.93 €	59.86 €
	Boring bucket		48.03 €
	Core barrel		68.86 €
Item BG 15			**5,314.25 €**

In the following step, individual item costs in the bill of quantities are determined. The computed workday rate for the large boring equipment including staff and construction site facilities is used where required.

Item 1.1

Installing the construction site requires special means of transportation, which also applies to clearing the site when the constructions are finished. Both together require two workdays, hence cost calculations have to assume this time frame.

Item 1.2

Equipment: BG 15	2 WD x 5,314.25 €/WD	10,628.50 €
Special transport (fixed)	4,000 €	4,000.00 €
Transport of equipment	2 x 150 km x 3.20 €/km	960.00 €
Other costs (fixed)	500.00 €	500.00 €
		16,088.50 €

Item 1.3

Boring rate	50 m/WD	
Concrete C 25/30	85.00 €/m³	
Excess concrete	10 %	
Pile diameter:	880 mm (radius: 440 mm)	
Boring (BG 15)	5,314.25 €/WD/50m/WD	106.29 €/m
Concrete	0.44 m x 0.44 m x π x 85.00 €/m³	51.68 €/m
Excess concrete	0.10 x 0.608 m³/m x 85.00 €/m³	5.17 €/m
Disposal of cuttings	0.608 m³/m x 25 €/m³	15.20 €/m
		178.34 €/m

Item 1.4

Reinforcement	950.00 €/t	**950.00 €/t**

Item 1.5

Number of piles	64	
Overheight concrete	0.5 m	
Subcontractor price (chipping)	250.00 €/m³	
Disposal costs	30.00 €/m³	
Chipping	0.608 m³/m x 0.5 m/pc x 250.00 €/m³ x 64 pc	4,864.00 €
Disposal of cuttings	0.608 m³/m x 0.5 m/pc x 30.00 €/m³ x 64 pc	583.68 €
		5,447.68 €

Item 1.6

1/10 Item BG 15	5,314.25 €/WD/10h/WD	**531.43 €**

To calculate the unit price, a value of 25 % is added on to all estimated costs to allow for general overheads, site overheads, and risk and profit. Since boring processes are routinely performed in heavy construction, potential bidding companies have plenty experience with respect to the added value; so, in this case, flat rates can be assumed for the calculations.

Table 2.60 Calculation of the unit prices of foundation engineering

Item	Costs (EUR/Unit)	Unit price = costs x 1.25 (EUR/Unit)
1.1	16,628.50	20,785.63
1.2	2,375.00	2,968.75
1.3	178.34	222.93
1.4	950.00	1,187.50
1.5	5,447.68	6,809.60
1.6	531.43	664.29

2.6.3.2 Soldier pile wall

In order to calculate costs using this construction method, it is imperative to include all costs that are incurred for the creation of one pit section (see Figure 2.34). Costs are mostly determined via the constructed visible surface area and have to be allocated accordingly.

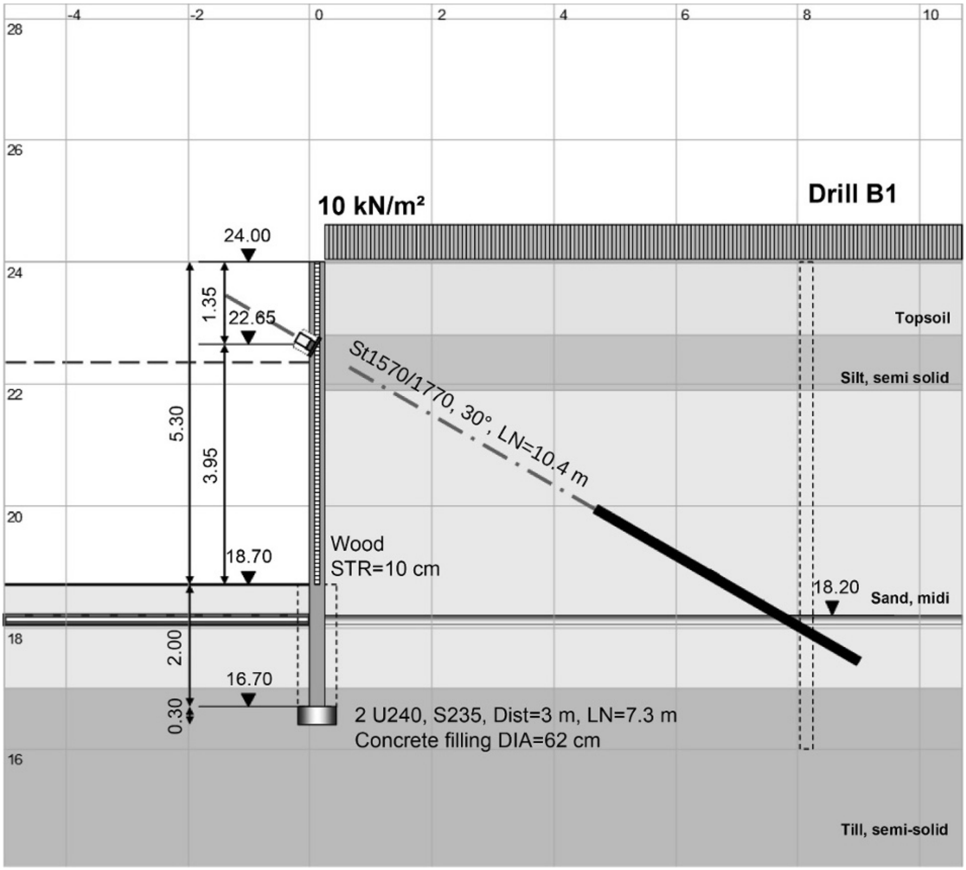

Figure 2.34 System sketch soldier pile wall

Steel beams

Rental period	3 months	
Clippings	100.00 €/t	
Transported quantity	20 t	
Transport distance	150 km	
Transport costs	3.20 €/km	
Attrition flat rate	200.00€	200.00 €/t
Rent	3 months x 30 CD/month x 0.45 €/t x CD	40.50 €/t
Clippings	100.00 €/t	100.00 €/t
Transport	2 x 150 km x 3.20 €/km/20 t	48.00 €/t
		388.50 €/t

Subsequently follow per-workday cost calculations for the future removal of the pit linings (extraction equipment).

Staff	2 employees with 50.00 €/h
Working hours	10 h/WD
Installed capacity	54 kW
Rate of utilization	0.5 of workday
Diesel	1.20 €/l
Operating fluids consumption	0.263 l/kWh

Costs		**EUR/WD**
Staff	10h/WD x 2 x 50.00 €/h	1,000.00 €
Equipment		
Truck-mounted crane	10h/WD x 150.00 €/h	1,500.00 €
Compactor		151.20 €
Generator		196.33 €
Workshop container (3 m)		14.38 €
Operating fluids	54 kW x 0.5 x 10 h/WD x 0.263 l/kWh x 1.20 €/l	85.21 €
Pos. Extn. Eqpt.		**2,947.12 €**

Afterwards, construction costs for the soldier wall pit linings are calculated. Costs for the wooden pit linings are directly inquired on the market, and a respective subcontractor is assigned with the actual performance.

The following calculations concern the construction of a soldier pile wall pit lining with a clear height of up to 5.30 m, sinking of pile bores into soil classes 3–5, assembly and disassembly of structurally required supports and wooden pit linings, availability of supports for three months, and delivery and installation of structurally required anchors. Activities are billed per square meter of visible surface area in accordance with structural engineering calculations.

Boring rate:	60 m/WD	Anchor length:	10.4 m
Extraction rate:	100 m/WD	Bore m³/m:	0.31 m²
Clear height:	5.30 m	Bore cuttings:	on site
Anchoring depth:	2.30 m	Concrete: C 08/10:	75.00 €/m³
Support spacing:	3.00 m	Timber:	45.00 €/m²
Support weight:	70 kg/m	Anchor:	60.00 €/m

Boring	(5.30 m + 2.00 m)/60 m/WD x Item BG 15	645.57 €
Extracting	(5.30 m + 2.00 m)/100 m/WD x Item Extn. Eqpt.	215.14 €
Base concrete	2.30 m x 0.31 m² x 75.00 €/m³	53.48 €
Sand concrete	5.30m x 0.31 m² x 55.00 €/m³	90.37 €
Supports	(5.30 m + 2.00 m) x 70 kg/m/1,000 x 388.50 €/t	198.52 €
Anchor	10.4 m x 60.00 €/m	624.00 €
Timber	5.30 m x 3.00 m x 45.00 €/m²	715.50 €
		2,542.58€

Recalculation to billing per square meter of visible surface area:

1/(5.30 m/3.00 m) x 2,542.58 EUR = 159.91 EUR/m²

The markup for business overheads, risk and profit is 25 % resulting in a unit rate of

(159.91 EUR/m² x 1.25) = 199.89 EUR/m².

2.6.3.3 Sheet pile wall

Calculations for the sheet-piling construction method involve, again, all costs accumulated during creation of the sheet pile wall based on the realized square-meters of the wall. In contrast to the soldier pile wall, costs are not billed on the basis of visible surface area but according to actual constructed surface area. Smaller contracts for sheet pile walls less than 10 meters in length, constructed under ordinary geological conditions are often subcontracted to regional companies which, due to the respective cost structure such as limited stock of equipment and equipment, are able to realize small contracts more cost-effectively.

For the construction, a rented RG 16-T, as base unit, and an MR 105 compactor are employed. In this example, the pile wall remains in the ground permanently and is not going to be extracted later, respectively. Consequently, material costs for Larssen sheet piles have to be included in the calculation in total. Furthermore, the construction does not require special prerequisites or measures, such as pre-boring of sinking trenches due to densely compacted soil layers, or similar (soil replacement bores, water boring, etc.).

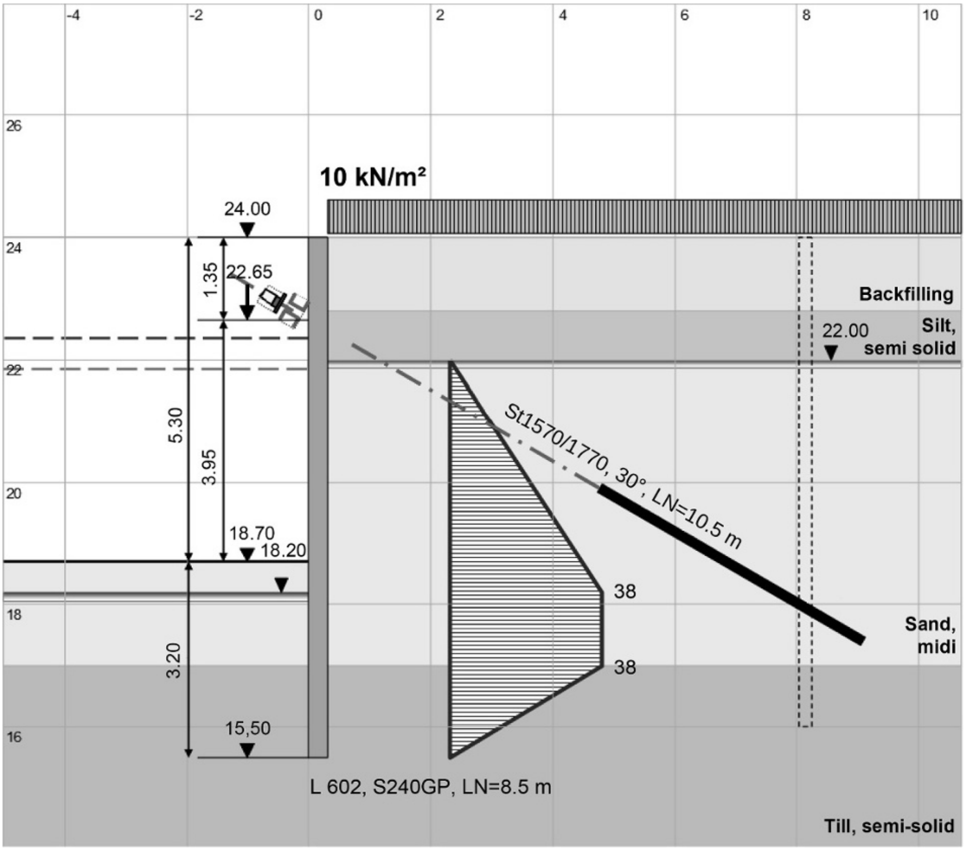

Figure 2.35 System sketch sheet pile wall

First, workday-related equipment costs are determined.

Staff:	3 employees à 50.00 €/h
Working time:	10 h/WD
Installed capacity:	380 kW
Rate of utilization:	0.5 of workday
Diesel:	1.20 €/l
Operating fluids consumption:	0.263 l/kWh

Costs			**EUR/WD**
Staff	10 h/WD x 3 x 50.00 €/h		1,500.00 €
Equipment:			
Rig RG 16-T (380 kW)			1,897.29 €
Compactor MR 105			295.04 €
Grippers MSU 54		2 x 55.35 EUR	110.70 €
Containers			
Workshop container (3 m)			7.78 €
Accommodation container (3 m)			10.25 €
Sanitary containers			12.25 €
Operating fluids	380 kW x 0.5 x 10 h/WD x 0.263 l/kWh x 1.20 €/l		599.64 €
Item RG 16-T			**4,432.95 €**

Subsequently, construction costs are calculated, which entails the creation of an anchored sheet pile wall with a clear height of 5.30 m and includes the following partial activities:

Sinking of sheet piles into soil classes 3–5 at ground water level to form a watertight construction pit.

Delivery and installation of structurally required sheet piles.

Activities are billed per square meter of constructed surface area in accordance with structural engineering calculations.

Rate of pile sinking:	200 m²/WD
Clear height:	5.30 m
Total length:	8.50 m
Anchor length:	10.50 m
Anchor spacing:	2.40 m
Pile weight:	89 kg/m² (Larssen 602)
Sealing material:	10.00 EUR/m² (SIRO HOESCH 88)
Material costs of Larssen piles:	1,200.00 EUR/t
Bracing (assy. and disassy.):	200 EUR/m

Costs		**EUR / WD**
Timbering, compacting	1 / 200 m² / WD x Item RG 16-T	20.71 € / m²
Larssen piles (permanent)	89 kg / m² / 1,000 x 1,200.00 € / t	106.80 € / m²
Sealing		10.00 € / m²
Anchor	10.5 m x 60.00 € / m / 8.50 m / 2.40 m	30.88 € / m²
Bracing	200 € / linear meter / 8.50 m	23.53 € / m²
		193.37 € / m²

The surcharge for general overheads, risk and profit is 25 % resulting in a unit price of (193.37 € / m² x 1.25) = 213.46 € / m².

2.6.3.4 Complete bill of quantities

Following is a complete bill of quantities, which highlights that the different construction methods therein exhibit different cost structures. For example, material components required for sheet pile walls, particularly since they are to remain as permanent installations, amount to almost 50 % of total costs (cf. example). Remaining costs are allocated virtually evenly to equipment and wages. Material costs, i.e. concrete and reinforcement bars, for large bored piles, in contrast, account for 40 to 50 % of total costs; and, last but not least, employing the soldier pile wall method where materials are “merely” rented and installations are temporary, costs are distributed almost evenly among equipment, wages, and material renting.

Excluded in the calculation are individual items for installation and clearing of construction sites or pits, which have to be either entered into the calculation for the pit-lining price or can be included in the main bill of quantities as general construction-site installation.

Item	**Text**	**Qty.**	**Unit**	**Unit price (EUR/Unit)**	**Total (EUR)**
	Title 1: Pile Foundation				
1.1	Installation and clearing of construction site in order to perform following special foundation work. Rate includes following activities: – Transport/delivery of required equipment, equipment, transport vehicles, etc. – Assembly/disassembly of required equipment, equipment, transport vehicles, etc. – Resources, including project staff, for uninterrupted operation of rotary boring rig	1	ea	20,785.63	20,785.63

1.2	Creation of verifiable structural engineering calculation and plan of realization (five copies) for offered activities in conjunction with the following specifications: – Relevant reaction forces on top edge of pile, load-bearing data per pile – Calculation criteria and geological survey – Cross-sectional view of top edge of bored pile including reference points to geological survey and planned construction – Site layout including elevation values	1	ea	2,968.75	2,968.75
1.3	Manufacture of in-situ large bored concrete piles with diameter of 880 mm acc. DIN 4014 and DIN EN 1536, respectively, including the following partial activities: – Sinking of piles into soil acc. Survey – Create empty bores – Delivery and integration of pile concrete C25/30, XC4, XF1, XA1 – Disposal of borehole cuttings – Pile length of 8.00 to 11.00 m; performance is billed per meter of pile measured from target top edge of pile and structure connected to bottom edge, respectively, to bottom edge of actual bored depth acc. manufacturer specifications	750	m	222.93	167,197.50
1.4	Delivery and installation of pile reinforcement; incl. following activities: – Delivery of reinforcement cages consisting of BSt 500 S for structural and constructional reinforcement – Installation of cages into bores; performance of reinforcement cages including required materials, such as flat steel, x-bases, support rings, spacers, etc. billed acc. steel schedules	10	t	1,187.50	11,875.00

1.5	Creation of in-situ concrete pile tops for addition of pile top plate and structure connected to pile, respectively; including the following partial activities: – Cuttings/exc. mat. transferred to ownershipofcontractoranddisposed Pile diameter maximum of 880 mm height tolerance +/- 3 cm billed per piece of chipped off bored pile top	1	ea	6,809.60	6,809.60
1.6	Optional item: Add. person hours for removal of boring obstructions. Debris disposed by construction staff.	5	h	664.29	3,321.45
	Total Section 1				**212,957.93**
	Title 2: Pit-lining Work				
2.1	Delivery and creation of Berlin-type pit linings (construction depth up to 5.30 m (visible area)). Ensure availability of linings including required bracings and anchors with subsequent removal after work completion. Structural engineering calculations provided by client. Installation to proceed in consultation with construction site management.	700	m^2	199.89	139,923.00
2.2	Delivery and creation of permanent, watertight sheet tile wall (construction depth up to 5.30 m) including required anchors.	1,200	m^2	241.71	290,052.00
	Title 2				**429,975.00**

Summary

Section 1 - Pile Foundation	212,957.93 EUR
Section 2 - Pit-lining Work	429,975.00 EUR
Bid sum total (exclusive of VAT)	642,932.93 EUR
VAT (19 %)	122,157.26 EUR
Bid sum total (including VAT)	765,090.19 EUR

2.6.3.5 Diaphragm wall

In accordance with the ever-present topical saying “A passed flood is not a flood of the past”, the following paragraphs focus on methods employed to increase flood protection to conclude the topic of this article. Questions arising in the area of preventive flood protection are still of importance and only partially solved. Thus, levees are constructed with sealing solutions on the inside wall using various techniques (sheet pile wall, mixed-in-place wall, diaphragm wall, etc.).

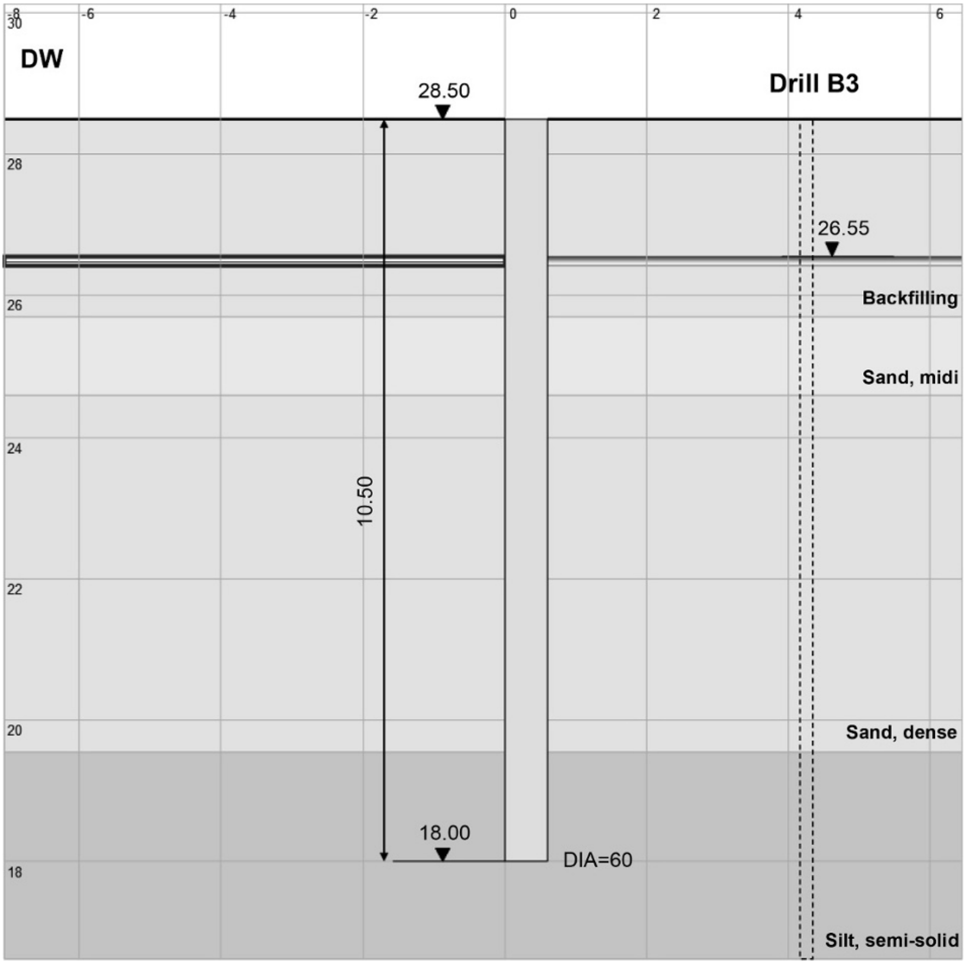

Figure 2.36 Diaphragm wall

Following are calculations for the diaphragm-wall construction method.

Equipment	Liebherr HS 855 with grabber
Staff	4 employees at 50.00 €/h
Working time	10 h/WD
Installed capacity	Diesel: 510 kW
Electricity	150 kW
Rate of utilization	0.65 of workday
Diesel	1.20 €/l
Operating fluids consumption	0.263 l/kWh

Costs		**EUR/WD**
Staff	10 h/WD x 4 x 50.00 €/h	2,000.00
Base unit	HS 855 (510 kW)	1,441.66
Grabber Stein K420		433.55
Buckets Stein	B600	91.57
Chisel	BSM 60	115.58
Monitoring system		200.00
Operating materials		
Diesel	510 kW x 0.65 x 10 h/WD x 0.263 l/kW/h x 1.20 €/l	1,046.21
Electricity	150 kW x 0.65 x 10 h/WD x 0.25 EUR/kWh	243.75
Mixing plant		
mixer with feeding screw		
water and bentonite tanks		
bentonite silos		948.75
Pumps		53.78
Containers		
workshop container (3 m)		7.78
accommodation cont. (3 m)		10.25
laboratory container		15.89
Wheel loader	6 t	
Item BS_855G		6,964.99

After calculating costs for equipment operation, the ascertainment of construction costs for the diaphragm wall follow.

Diaphragm wall width:	0.60 m
Hardening material:	ready mix SOLIDUR® 274S with 250.00 €/t
Quantity:	300 kg/m³ slurry
Performance rate:	150 m²/WD
Water price:	3.00 EUR/m³
Add. slurry consumption:	35 % (depending on method and soil between 20 and 40 %)
Loosening factor:	1.4

Wall cutting	BS_855G 1/150 m²/WD x 6,964.99 €/WD	43.72 €/m²
Hardening material	SOLIDUR ® 274S 0.60 m x 1.35 x 0.3 t/m³ x 250.00 €/m³	60.75€/m²
Water	0.60 m x 1.35 x 0.9 t/m³ x 3.00 EUR/t	2.19 €/m²
Disposal of cuttings	0.6 m³/m² x 1.4 x 35 EUR/m³	29.40 €/m²
Attrition of grabber (experience value)		5.00 €/m²
		143.77 €/m²

The surcharge for general overheads and risk and profit is 25 % resulting in a unit price of (143.77 €/m² x 1.25 =) **179.71 €/m²**.

Methods to save resources for diaphragm-wall constructions have been on the rise in recent years. They include, for example, “mixed-in-place” walls or “cutter soil mixing” techniques where soil is mixed in-situ with suitable binding agents and then homogenized. Through soil analyses, material solutions and required quantities of binding agents are determined. Due to an enormous reduction of transport volumes, economic and environmental benefits are clearly visible when employing these methods.

2.6.3.6 Conclusion

The presented methods give only an introductory outline of the techniques employed in the field of special foundation engineering as the range of activities offered by most civil engineering companies is much wider. The examples in this section demonstrate that a comprehensive understanding of each technique is essential, and hands-on experience plays a significant role for working with calculations in civil engineering.

In order to succeed in today’s construction market, further developments and even better construction techniques and methods are required. New technologies can provide the necessary competitive edge; and, to manage the large wealth of experience, meet requirements of public and private contracts, and handle bids, using the latest EDP technology for calculation processes is crucial. As was shown, the preparatory work performed prior to the start of construction (reviewing and verifying construction documents, geotechnical surveys, etc.) occupies a significant position in special foundation engineering. Last but not least, risk management and identification of reward opportunities are of pivotal importance to succeed as a civil engineering company.

3 Special aspects of the estimating process

3.1 Claim management

3.1.1 Introduction

In current construction practice, changes of contract details can play an important role in realizing the economic potential of a project. After the conclusion of a contract, large monetary expenditures, or longer construction periods may occur as a result of variations in specifications which were not known in the pre-calculation phase.

When used in the construction industry, the term ”variation” can be defined as a modification in the quality, quantity or design of a job, as defined in the relevant contract documents, which include drawings and bills of quantities. In heavy construction projects, at least minor variations are inevitable and the resulting claims may cause disruptions and/or financial losses.

In general, the three types of claims are:[1)]

1. Extension of time
2. Additional payments
3. Extension of time and additional payment

When dealing with changes in construction details, the variety of contracts illustrates the wide range of approaches available for handling these situations.

3.1.2 Contractual basics

The bases for evaluating variation orders are the respective contract documents, the jurisdiction of the specific country as well as Common Law. In current construction practice, the procedures for dealing with change orders are laid out in the contractual agreements. In Germany, these details are defined in additional terms and conditions in the form of the Construction Tendering and Contract Regulations (VOB) as well as the Civil Code (BGB). The Anglo-Saxon change order management is based on standard forms of contract including, but not limited to:

– JCT (Joint Contracts Tribunal)
– ICE (Institution of Civil Engineers)
– ICC (International Chamber of Commerce)
– NEC (New Engineering Contracts)
– FIDIC (Fédération Internationale des Ingénieurs Conseils)

To specify the details, these standard contract forms must be complemented by individual agreements between client and contractor.

1) Cf. Klee (2015).

Estimating in Heavy Construction. 1st Edition. Jacob, Müller (Eds.)

3.1.3 Chosen change orders during the construction process

There are multiple possible reasons for the raising of claims. The underlying cause is, however, always a modification of the contractual agreements.

Due to the complexity of larger construction projects, a variety of cases of variations can arise during the construction process.

These changes include, but are not limited to:

- Modified and/or additional activities (scope)
- Changed quantities
- Cancellations
- Disturbances of the construction process

Variation orders due to tempory effects, e. g. disruptions of construction activities, therefore tend to be the most frequent in the construction industry.

Legal aspects are not covered in this chapter. Nevertheless, they play a major role in the calculation, because only legally justified claims can be refunded.

In German VOB-contracts, the following abbreviated reasons for possible claims can be found:

- A *10 percent variation* in the quantity of mass. On request of a contractual partner, a new unit price that includes added and dropped costs has to be ascertained. When dealing with a decreased quantity of mass, a new possible quotation regarding other service items needs to be considered. The adjustment of the unit price is primarily based on the changed distribution of the construction site facility costs, the site overhead expenses, and the general overhead costs.
- *Changes of construction design* or other client orders that alter the pricing bases of an item.
- The demand of *additional activities* that are not part of the original contractual agreement but need to be executed to ensure the success of the construction project.

In Germany, the original calculation (in Germany „Urkalkulation“) serves as the basis for the pricing of the changed activities and items, meaning that in German VOB-contracts changes are not priced freely but with the aid of comparable items of the contract. Exceptions are additional activities, which cannot be compared to similar items in the contract. However, the surcharges for site on-costs and overhead costs from the original contract are used when pricing these activities.

Effects on the overhead are not assessed at this point, because they are not viewed as a separate position but as an impact on the whole project contract. Thus, diverse approaches are possible in the construction practice.

3.1.4 Example calculation

The following example is based on the earthwork example in chapter 2.2. The stated contractual details are changed considering the following facts and circumstances:

Item 01.02.10 (Soil and rock loosening, loading, transport and installation within the construction site) cannot be executed for a partial mass of 50,000 m³ as described. This partial mass is contaminated and cannot be installed on the construction site but needs to be moved to a disposal site referred to by the client for disposal. The main item can be used for the subprocess „Soil and rock loosening, loading and creating of the subgrade". The changes result from:

- Transportation within the construction site is dropped, but the transportation to the disposal site in the public transport area is added.
- It is assumed that the client directly pays the disposal fees to the operator which is installing the masses on the disposal site.
- As a consequence, the material installation is dropped from the original activity.
- It is supposed that the loading performance drops to 70 % because of the lower mass of loosened soil.

The above-mentioned adjustments are considered in the following calculation of the altered items. It is possible that these changes result in additional expenditures, which need to be noted for the overall claim. It is therefore conceivable that the finding of the contaminated material causes an increased testing effort in the earthwork activity. The billing effort could also increase, because a defined cubature needs to be measured, calculated, and marked in two parts. Additionally, the transfer of material within the construction site causes a change in the quantity of mass because the consumed mass might be missing during the soil application and needs to be replaced by supplied material. The performance reduction to 70 percent of the loading performance could also apply to the remaining mass of the original position. As a consequence, a new unit price or an extra allowance also needs to be agreed upon.

These issues can provide the bases for further items of this claim whether based on existing items or free calculation of new activities which are not yet agreed upon. Because the approach for these items is analogous to the following example, an individual consideration is left out at this point.

Calculation approach

1. Use of the original calculation of item 01.02.10

Ascertainment of the direct costs:

Portion for the loosening by the excavator+ loading 218.36 €/h/250 m³/h	0.87 €/m³
Portion for transport according to the example from section 2.2.3.5	3.60 €/m³
Portion for the installation: (173.62 +2 x 112.70 €/h)/250 m³/h	1.60 €/m³
Portion for the subgrade	
(135.00 + 16.85 + 103.76) €/h/200 m²/h x 0.2 m²/m³	0.26 €/m³
Sum of direct costs	6.33 €/m³
Plus overheads 20 %:	1.27 €/m³
Total unit price	**7.60 €/m³**

2. Calculation of the changed activity

Ascertainment of the direct costs:

Portion for the loosening by the excavator + loading

218.36 €/h/(250 m³/h x 0.7) 1.25 €/m³

Portion for the transport to the disposal site (Assumed external service offer including weighing and road-usage fee of 5.00 €/m³): 5.00 €/m³

Portion for the installation is dropped: 0.00 €/m³

Portion for the subgrade

(135.00 + 16.85 + 103.76) €/h/200 m²/h x 0.2 m²/m³ 0.26 €/m³

Sum of direct costs: 6.51 €/m³

Plus overheads 20 %: 1.30 €/m³

Total unit price: **7.81 €/m³**

Resulting from this calculation, a unit price of 7.81 €/m³ is billed for the changed activity.

Alternatively, the additional services could be offered in addition to the main item in the bill of quantities. This means that the main item accounts for all mass (50,000 m³ uncontaminated and 50,000 m³ contaminated). For the partial mass of the contaminated soil, the difference in the unit prices is additionally charged:

50,000 m³ x (7.81 €/m³ - 7.60 €/m³) = **10,500.00 €**

The advantage of this approach is the exact identification of additional and/or dropped costs compared to the original contract for an extra item.

3.2 Construction in foreign countries

Certain calculation processes come into play regarding the individual situation, for foreign (i.e. in countries other than Germany) construction engineering projects. These include bid sums, machine hours, and commodity trading calculations, as well as the income approach. Additionally, risks specific to the realization of projects in foreign countries (hereinafter referred to as country-specific risks) have to be considered, and related costs (such as Hermes coverage [export credit guarantee], retention, foreign exchange hedging) are included in the pre-calculation.

The following chapter gives a general overview of financial risks connected to foreign construction engineering projects and export trade business with particular attention on economics, political climate, and special risks. Subsequently, safeguard or protection options are described in conjunction with public and private export credit insurance, documentary credit (for component deliveries), and documentary collection. Later sections explain specific financing alternatives in foreign trade including supplier credit of the exporter, buyer credit, and forfeiting. The last chapters focus on special problems, such as provision of collateral and hedging activities in conjunction with forward exchange transactions, exchange option transactions, and foreign currency credits.[2)]

3.2.1 Financial risks and dispute resolutions

3.2.1.1 Risks

Foreign-specific risks can basically be divided into economic and political risks (cf. Figure 3.1).

With regard to *economic risks*[3)], the importer may be unwilling to accept goods delivered by the exporter (risk of refusal). Additionally, the importer may not comply with contractual payment obligations (payment risk), while the exporter, on the other hand, may not deliver goods as per contractual agreement (supply or procurement risk). Lastly, exchange rate fluctuations are a risk for both sides. It should be noted that the previous risks emerge due to the fact that a simultaneous exchange of services and return services is not possible and because there are substantial differences between countries and their laws, regulations, and concepts regarding doing business. Moreover, the legal enforcement of individual positions may prove to be quite difficult. Economic risks mostly include microeconomic risks such as bankruptcy, liquidation, or fraud.

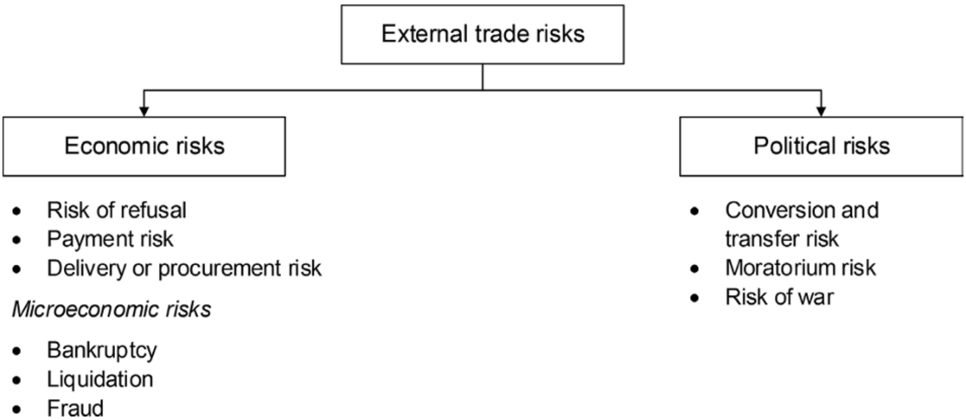

Figure 3.1 External trade risks

Political risks connected to external trade transactions include conversion and transfer, moratorium risks, and the risk of war. Conversion and transfer risks exist, in particular, in countries with compulsory exchange controls. As a result, payments successfully transferred to the bank of the importer may not be exchanged (converted) by the bank or it may be unable to transfer payments to the bank of the exporter. Moratorium risks involve the prohibition of foreign exchange exportation due to foreign policies. The

2) Endisch / Jacob / Stuhr (2000), pp. 534–540.

3) In accordance with Grill / Perczynski (2008), p. 471 f.

risk of war means the possible loss of assets before the transferal of risk to the customer.

The *particular risks associated with foreign construction projects*[4)] emerge primarily due to at least partial conclusion of the project ”on site” abroad, requiring additional advances, and expenses paid by the contractor. In this context, additional risks include, but are not limited to:

- Expenses for construction site installation
- Costs for construction site provisions
- Employment of owned or rental equipment in foreign countries and supply of spare parts
- Warehousing of equipment until reassignment
- Use of resources (financial means) during start-up period
- Downtime measures

The contractor may be subject to additional political risks, for example, in the form of construction disability through political activities in the debtor country or confiscation of assets.

3.2.1.2 Feasibility of conflict resolution

Conflicts on the basis of contractual matters cannot always be avoided due to the greater risks and problems in conjunction with external business. The field of conflict resolution is generally divided into public and institutional arbitration with ad hoc arbitration being a special form of conflict resolution. It should be noted that legal proceedings are a time-consuming endeavor, particularly if parties involved have to arbitrate bilingually through foreign and native legal institutions. Where public arbitration is concerned, problems may also arise over agreeing on or defining jurisdictions and the recognition and enforcement of German verdicts abroad. Table 3.1 lists institutions which apply institutional arbitration. Verdicts of the International Chamber of Commerce (ICC), headquarters located in Paris, find virtually global acceptance with respect to conflict resolution. The table also gives a preliminary overview on recognition and enforcement of non-native arbitral awards.

4) Cf. German Federal Ministry of Economic Affairs and Energy (2016).

Table 3.1 Arbitration in foreign countries

Recognition and enforcement of German verdicts	Institutional arbitration	Recognition and enforcement of foreign arbitral awards
• China: prevailing opinion: yes • India: disputed • Malaysia: yes • Singapore: yes • Thailand: no • Vietnam: questionable • Philippines: no	• International Economic and Trade Arbitration Commission • Malaysia: Kuala Lumpur Regional Centre for Arbitration • Singapore International Arbitration Centre • International Chamber of Commerce in Paris, Hong Kong offices do not offer administrative functions	• Convention on the Recognition and Enforcement of Foreign Arbitral Awards adopted on June 10 1958 • China: yes • India: yes • Malaysia: yes • Singapore: yes • Thailand: yes • Vietnam: yes • Philippines: yes

3.2.2 Safeguarding foreign construction projects and export transactions

3.2.2.1 General collateral

During loan transactions, it is imperative for the borrower to provide collateral with respect to the required loan amount for the lender. Collateral encompasses "contractual, direct entitlement to liquid assets" [5], which can be divided into physical and personal collateral (cf. Figure 3.2).

Physical collateral is defined as "contractual right to seizure of security objects"[6]. Securities objects can include both movable and immovable property as well as rights. Furthermore, personal collateral is understood as "the contractual acceptance of liabilities by third parties". Personal collateral is particularly relevant for export transactions in the form of surety bonds and guarantees.

5) Rollwage (2006), p. 23.

6) Ibidem, p. 24.

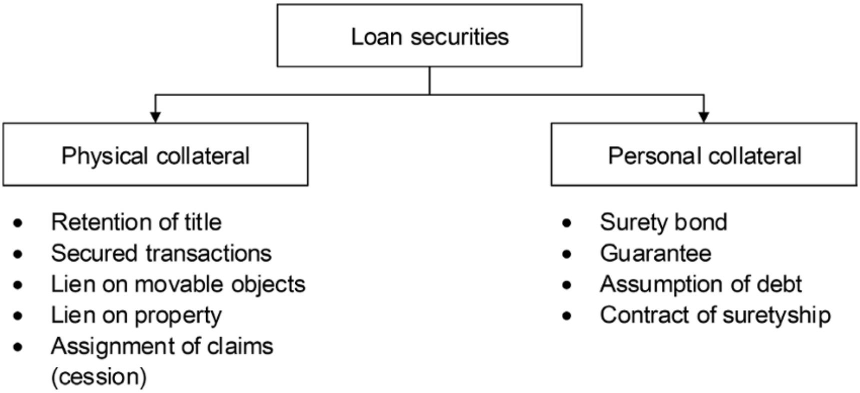

Figure 3.2 Loan collateral[7)]

A surety bond is a binding agreement between a guarantor and a creditor to a third party where the guarantor vouches for the fulfillment of obligations in case the third party defaults. Surety bonds are always accessory to existing claims.

In contrast, a guarantee is a contract that obliges a third party (guarantor) to vouch for a certain result or success - including hazards or damages[8)]. Contrary to surety bonds, guarantees are not regulated by law and are “legally disassociated with an underlying loan contract”[9)], which means that guarantees are notional promises of payment. Export guarantees and sureties of the Federal Republic of Germany (section 3.2.2.2), export credit insurance provided by private risk insurers (Section 3.2.2.3), letter of credit (section 3.2.2.4), and documentary collection (section 3.2.2.5) have been well established as a means of safeguarding against the risks emerging with export transactions.

3.2.2.2 Public export credit insurance

Most of the industrial countries offer public export credit ensurance. In the United States, the coverage comes from the Ex-Im Bank (i. e. the Export-Import bank of the United States). In the United Kingdom, the government organization is called ECGD (i. e. Export Credits Guarantee Department). German companies also benefit from financial coverage for political and economic risks related to export transactions. This is realized and enforced by a consortium built around the Euler Hermes SA (Paris) and PwC Deutsche Revision AG (Frankfurt am Main). Euler Hermes SA, as general manager, processes public export guarantees on behalf of and on account of the Federal Republic of Germany and is thus an instrument to protect export.

7) Cf. ibidem, p. 24.

8) Grill / Perczynski (2008), p. 374.

9) Ibidem, p. 374.

Types of coverage

With respect to export guarantees, the following Euler Hermes coverage types exist:

– Export guarantees "if the foreign contractual partner of the German exporter is a privately organized company"[10)]
– Export surety bonds "if the foreign contractual partner of the German exporter or their designated debt risk guarantor is a fully liable sovereign state, local authority or similar institution"[11)]

Export guarantees can be granted to German exporters for risks before shipping (manufacturing risk coverage) and for risks after shipping (export coverage) (cf. Figure 3.3).

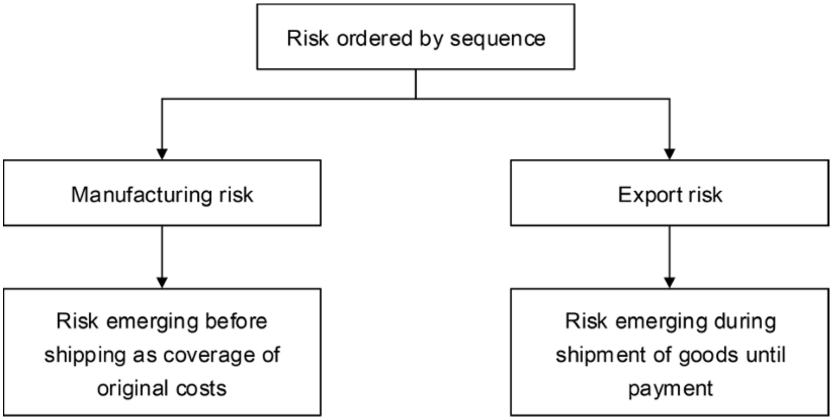

Figure 3.3 Risks ordered by sequence

"Manufacturing risk coverage means coverage of original costs for the exporter until the initial end of the production process as a result of emerging covered risks due to the fact that production or shipment of goods is made impossible because of political or economic issues or has become unreasonable for the exporter. Export coverage protects the exporter from uncollectibility of demanded export goods due to political or economic reasons over the time frame that goods are shipped or services rendered to receipt of payment in full. The object of the claimed coverage is the contractually agreed amount of payment as return service in the export contract with the foreign debtor, including loan interest accrued until the time of payment"[12)].

In any case, the recipient of coverage bears a certain percentage as deductible in the event of damage, which usually amounts to 10 % for political risks and 15 % for non-payment risks with respect to export guarantees and surety bonds. Whereas the deductible for manufacturing risk guarantees and surety bonds comes to about 10 % for any risks. Risk that results from the deductible may not be covered through further

10) Cf. German Federal Ministry of Economic Affairs and Energy (2016).

11) Ibidem.

12) Ibidem.

means. An actual reduction could be achieved through pre-payment or deposit agreements.

Application procedure and fees
The application for transfer of export guarantees should be filed with the Euler Hermes SA during the later stages of contractual negotiations since, on the one hand, processing of applications requires a certain amount of time and, on the other, potential provisions and restrictions might come under consideration. It should be noted that fees are incurred when filing an application.

The applicant is required to pay fees for application processing in the form of an "application fee", "issuing fee", and "extension fee". Moreover, Hermes charges a fee for accepted export guarantees, the amount of which depends on country ranking, customer ranking of the applicant, coverage form, amount of covered claims, and payment conditions. Since not all countries qualify for minimum ranking criteria, Hermes does not offer coverage globally. In annual export transaction coverage reports, Hermes updates selected country information, current categorizations, and the latest country rankings. Countries that do not have a mutual investment incentive agreement with Germany as per December 2013, are listed in Table 3.2 as follows.

Table 3.2 List of countries not included in export transaction coverage by Hermes[13)]

Brazil (not yet included)	Iraq
Colombia	Libya (not yet included)
Czech Republic	Myanmar
Dominican Republic	South Africa (cancelled on 10/13)
Eritrea	Seychelles
Gambia	Taiwan

Custom Hermes coverage for the construction industry
Specific risks that emerge during the realization of construction projects in foreign countries due to production on site are also covered as part of the framework of export guarantees by the Federal Republic of Germany. Here, Hermes differentiates between construction works and construction equipment coverage (cf. Figure 3.4). In case the construction work is continually paid with construction progress, special discounts are granted.

13) Cf. Euler Hermes Aktiengesellschaft (2016.)

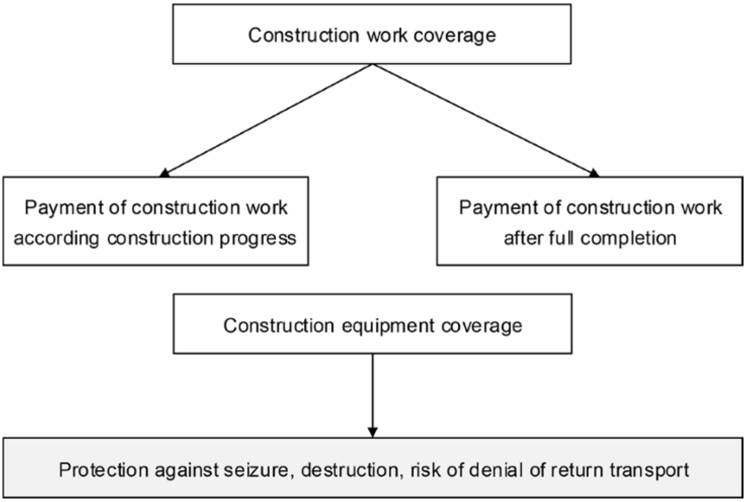

Figure 3.4 Public Hermes coverage tailored to the construction industry

Table 3.3 Types of coverage for construction works projects[14)]

Type of coverage	Covers ...
Construction works claim	Bad debt
Construction site cost coverage	Estimated costs of construction site installations if realization of the project becomes unreasonable or impossible for the coverage recipient, and regular expenses of construction site installations as per contractual price can no longer be covered due to political reasons or increasingly hazardous conditions in the foreign country
Supply cost coverage	Expenses accrued as a result of supplies required for realization of project and stored on-site if they can no longer be covered due to reasons above
Equipment coverage (Special type: Global equipment coverage)	Risk of seizure or destruction of construction equipment due to political reasons
Warehousing coverage	Assembly and construction equipment warehoused after expiration of equipment coverage
Spare parts depot coverage	Equipment spare parts up to 20 % of equipment value
Operating materials	Conversion and transfer risks of operating materials
Downtime costs	Expenses accrued by possible, temporary interruption of project realization

14) Based on the German Federal Ministry of Economic Affairs and Energy (2016).

3.2.2.3 Private export credit insurance

Private risk insurance institutes include Atradius, Coface Deutschland, and Euler Hermes SA, among others, which offer export credit insurance for export transactions. They usually cover economic risks (insolvency risk). In order to cover political risks and be on the safe side, export guarantees provided by the government should be considered.

3.2.2.4 Documentary credit

Definition and document creation
Documentary credit (or letter of credit) is

- conditional (credit conditions, e. g. required documents),
- fixed-term (credit terms such as validity, date of shipment, document delivery deadline),
- notional (not connected to underlying transaction of goods),
- (irrevocable).

promise of payment made by the issuing bank to pay a certain amount (credit amount) to the beneficiary (exporter).

In contrast to public Hermes coverage, the full claimed volume of goods can be covered by a letter of credit without deductible. Figure 3.5 and Figure 3.6 visualize the general process as flow charts.

After a purchase agreement, e. g. for the delivery of components, has been finalized between exporter and importer (1), the importer tells its bank to issue a letter of credit (2). Should the circumstances require, a confirmation statement should be considered, as soon as transactions are concluded, as part of the letter of credit. Subsequently, the bank of the importer (issuing bank) issues the letter of credit in compliance with the bank of the exporter (advising bank) (3). The exporter examines content and duration of the received documentary credit and discusses possible protection measures with their bank. After notification (4), goods are delivered by the exporter (5), who afterwards submits required documents to their bank (6) and receives respective credit or payment (7). The advising bank delivers the documents to the issuing bank (8). In a last step, the issuing bank hands the documents to the importer and charges their account with the appropriate figure (9).

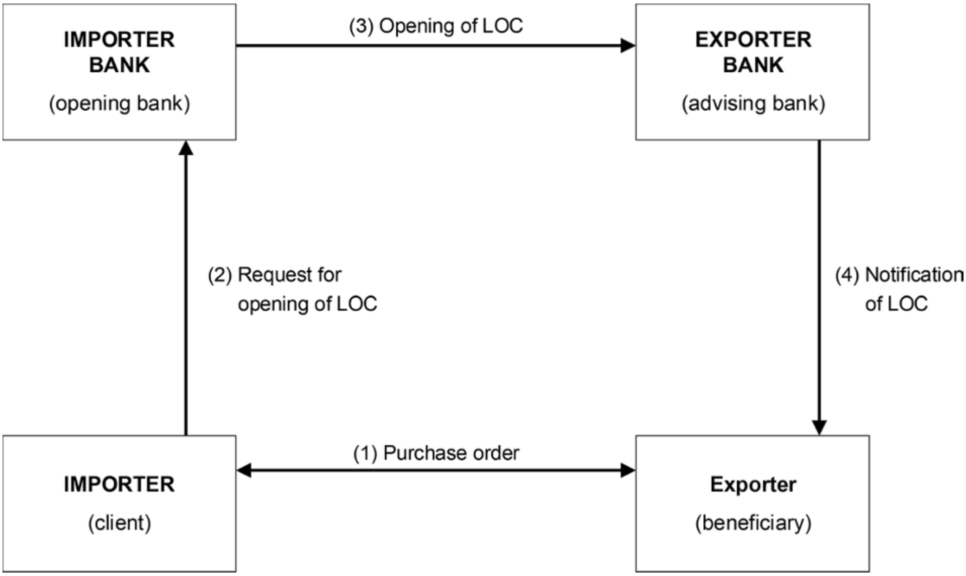

Figure 3.5 Documentary credit, point I (prior to delivery of goods)

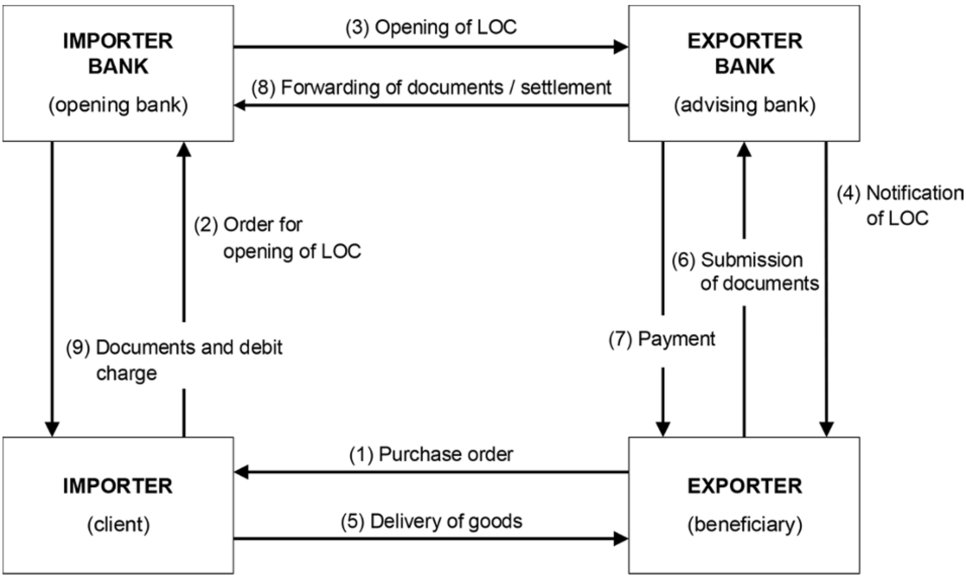

Figure 3.6 Documentary credit, point II (continued after delivery of goods)

A letter of credit is a notional monetary instrument meaning:

- Banks involved are not legally bound to the underlying transaction.
- Required documents filed as part of the documentary credit transaction may only be reviewed by banks within the confines of the present letter of credit and provisions defined by UCP 600 (Uniform Customs and Practice for Documentary Credits, ICC Publication No. 600).
- Any agreements between exporter and recipient may not be considered during review, provided they are not part of the letter of credit.
- Even minor discrepancies in the documents can lead to a loss of payment protection and payment delays respectively.

Thus, the following basic principles can be deduced for the creation of credit documents:

1. All documents have to comply with regulatory conditions in the letter of credit as well as general UCP-600 regulations
2. The documents may not contradict one another (e. g. by using different tags or meta-text information)
3. All documents should refer to the letter of credit in some way (e. g. through documentary credit number)
4. Documents have to be submitted within the specified deadline in the letter of credit (unless otherwise specified within 21 days after shipment)

Protection measures, fees, and risks

Employing the type of *confirmed letter of credit*, the "confirming" bank (usually the advising bank) documents its individual promise of payment in the letter of credit in addition to the promise of payment made by the issuing bank. Country-specific risks are thusly transferred to the confirming bank to the benefit of the exporter. However, additional costs for the exporter are accrued as part of the confirmation process (confirmation commission / deferred-payment commission). The commission amount depends on the country-specific risks meaning confirmations are provided only if credit arrangements are possible with the bank issuing documentary credit. Lastly, confirmation orders are difficult to obtain in certain countries such as Iran or China.

A *purchase commitment* is similar to a confirmation. In this case, the exporter instructs the advising bank to supply protection measures (not part of the letter of credit). As the advising bank is, legally speaking, in a weaker position using this instrument. A purchase commitment is usually more expensive than a confirmation.

A *protection guarantee* is similar to a purchase commitment but is provided by a third-party bank, which is not part of the consultation process (only part of the handling process). Certain *fees* or commissions are charged when employing documentary credit. Table 3.4 gives an outline of fees and commissions in accordance with country-specific rankings.

Table 3.4 Outline for documentary credit fees

As of March 2010

Assumptions: 1,000,000.00 EUR, duration including deferred-payment period of six months						
Country rating	0	1	2	3	4	5
Examples	France	Hong Kong	Saudi Arabia	Mexico	Philip-pines	Indonesia
Advising commission	0.10 %	0.10 %	0.10 %	0.10 %	0.10 %	0.10 %
Handling commission	0.30 %	0.30 %	0.30 %	0.30 %	0.30 %	0.30 %
Confirmation commis-sion	0.50 %	0.50 %	0.80 %	1.00 %	2.00 %	2.25 %
Deferred payment com-mission	0.15 %	0.25 %	0.27 %	0.30 %	0.35 %	1.30 %
Total	1.05 %	1.15 %	1.47 %	1.70 %	2.75 %	3.95 %
Percentages refer to amount of documentary credit. Advising commission: Fees of advising (foreign) bank. Handling commission: Fees for document reception by the domestic bank and domestic handling. Deferred-payment commission: Protective fees for post-review period provided that documentary credit conditions are met. Confirmation commission: Cash-out commitment of the confirming bank provided that documentary credit conditions are met.						

Documentary credit fees should be considered in the calculation process. The following risks may arise when employing documentary credit:

1. Certain documentary credit conditions (e. g. delivery dates or required documents) cannot be met
2. Documentary credit conditions do not match the contract (e. g. type and volume of delivered goods or delivery conditions)
3. An agreement that certain documents have to be provided, which the recipient is supposed to create (so-called strain) may result in a situation of overdependence on the recipient
4. The credit rating of the foreign bank is insufficient
5. The country-specific risk of the recipient country is high
6. Documents are inconsistent. Smallest discrepancies can lead to a loss of payment protection or delays in payment
7. The letter of credit is not issued on time

3.2.2.5 Documentary collection

Documentary collection involves processing of scrupulously defined documents by banks with the intention of receiving payment. Usually, the order is given by the exporting bank client, who entrusts the collection process to their bank, which is legally based on ICC provisions for credit and collection. Contrary to letters of credit, which is one of the most secure types of credit transaction, documentary collection processes should be regarded with due skepticism since the processing bank is merely a sort of postal service, which reviews documents but is not subject to liability in case the foreign recipient of goods defaults on its payments.

3.2.3 Hedging foreign exchange transactions

Exchange hedging measures should be employed in case exchange incongruities arise between cash receipts and disbursements. The most common type of exchange account and obligation hedging is issuing a respective transaction on the currency futures market (called a *forward exchange transaction*), which provides a secure calculation basis regardless of future delivery or performance dates. Forward exchange transactions means an agreement to a future exchange of currencies detailing required items including, in particular, amount, exchange rate, and date of transaction. The agreed exchange rate at the time of contract maturity, called the forward rate, is dependent on two factors - the current spot rate and an addition to or deduction from the spot rate. The added or deducted amount, called premium or discount respectively, reflects the interest difference between contracted currencies.

A further means of exchange hedging is provided by *currency option transactions*. Similar to forward exchange transactions, an agreement is made against payment of an option premium over a future transaction of currencies including determination of amount, exchange rate, and option expiration date. In contrast to a forward exchange transaction, the client is not obliged to the currency transaction and is hence free to choose whether to use the option until its expiration date or forfeit it. The market volume for hedging through currency options is limited and is both comparatively expensive and restricted to certain currencies.

Lastly, it should be noted that *foreign currency loans* are available as alternative, which would be repaid through the cash flow of the project.

3.3 Calculation of risks

Risks may be examined according to their function or according to their appearance in the life cycle of a structure. Risks that may emerge in the construction sector have to be evaluated, for which certain instruments are available. Alternatively, risks may also be transferred to third parties.

3.3.1 Major functional risk sectors

Every entrepreneurial action is necessarily connected to risks that should remain calculable. The following are important risk-policy principles:[15)]

- Attainment of economic success is *always* connected to risks
- No actions or decisions may result in *existence-threatening* risks
- Earning risks need to be adequately refined by *return of investment*
- Risks should be controlled by *instruments* of risk management
- According to a study carried out by a large construction company, of all risks:[16)]
  - 63 % are assigned to the pre-contractual phase (41 % to erroneous calculation, 22 % to contractual risks)
  - 30 % are assigned to the realization of the construction
  - 7 % are assigned to higher force

The task force construction business management of Schmalenbach-Gesellschaft more closely examined three partly overlapping risk sectors. These include customer risks, contractual and connected calculation risks, as well as risks emerging during construction work.[17)]

3.3.1.1 Customer risks

Customer risks mainly result from the high complexity of the individual contractual order in conjunction with the high value of the individual order (particularly with respect to fixed-price contracts), as well as the longevity of the processing of orders, the high purchasing risk, the high number of one-time customers as well as, in cases where applicable, foreign risks. A number of customer-related risks exist that differ greatly from other business sectors. Among these are credit risk, contractual risk, risk of customer dissatisfaction, customer success risk, and customer change risk.

Credit risk denotes the basic inability to pay customers and customer groups and also time of payment, whereas contractual risk is closely related to a high number of one-time customers. While the most contracts are project-specific individual contracts, the successful treatment of specific contract provisions varies from customer to customer.

The risk of customer dissatisfaction is the risk of coming into conflict with the customer during the project due toissues such as lack of quality, deadline conflicts, or costs, and the resulting post-construction issues such as purchasing risk, warranty risk, penalty risk, or performance risk. Customer success risk, which means the risk of a customer not having conceptualized their project according to the financial requirements, that the construction industry often pays little attention to. With regard to the control of this risk factor, it should be in the construction company's interest to assess the success potential of a construction project from the customer's point of view. Lastly, customer change risk includes difficulties connected to changing or exchange of contractual part-

15) Cf. Birtel (2000), p. 8 f.

16) Cf. Linden (1999), p. 9.

17) Cf. Zentralverband des Deutschen Baugewerbes/Betriebswirtschaftliches Institut der Bauindustrie GmbH (Ed.) (2000).

ners or team members caused mainly by the long-term nature of project realization in the construction sector. Particularly, large orders are usually commissioned by anonymous organizations, which are subject to change over the course of time – for example, due to changing decision-makers[18].

Instruments of customer-oriented risk management may be separated into two groups. The first group of which is comprised of the traditional instruments of the trade credit insurance companies and the second group consisting of entrepreneurial instruments (cf. Table 3.5).

Table 3.5 Customer-oriented instruments of risk management[19]

Traditional instruments of trade credit insurance companies	Entrepreneurial instruments

– Annual reports
– Bank reference
– Voluntary disclosure
– Experiences with payment reliability
  – Setting and monitoring of funding limits
  – Development and adherence to a catalog of business conditions requiring consent
  – Assembly of a catalog of purchasers subject to authorization
	– Key account management
	  – Organization of servicing key clients
	  – Conducting client interviews
	  – maintaining client contact during the construction phase
	– Project orientation (technical as well as commercial consideration and assessment of construction projects by the executing company)
	– Contract orientation (systematic, technical, commercial, and legal contract inspection during offer and order phases as well as respective service during the realization phase)

3.3.1.2 Contractual and calculatory risks

Since the calculation process is directly dependent on the commitments articled in the contract, contract and calculation-risks are closely connected.

Risks emerge according to the type of contract, which may include underlying unit price contracts, lump-sum contracts (general, detailed lump-sum contracts), general transfer contracts, functional construction contracts, turnkey construction contracts, guaranteed maximum price (GMP) contracts, operator contracts, renovation contracts, and contracts over the entire life cycle, such as build, operate, transfer (BOT) contracts (cf. section 2.1.4). Moreover, a defining factor towards the distribution of risks is the respective payment mechanism. The more the company has to pay in advance, the graver are the risks for the company, and the more risk capital has to be provided.

18) About the remarks concerning customer risks cf. Birtel (2000), pp. 7–16.

19) Cf. ibidem, p. 15.

The calculation method, besides contract type and intended scope of performance, depends on the construction sector. Construction sectors may include: Industrial construction, housing construction, commercial construction, public construction, special foundation engineering, tunnel construction, or road construction. Depending on the production method employed in the particular construction sector, machine-related and convoy-related calculation, respectively, wage-related calculation, acquisition-related calculation, or a hybrid form dominate (cf. chapter 2.1.5).

Regarding the precise calculation and contractual management, a differentiation into six categories can be made:[20)]

- Offer calculation and price formation
- Setting of boundary conditions for the construction object
- Devolution by the commissioner
- Construction site organization and management
- Employment of subcontractors
- Contractual qualifications

The spectrum of risk ranges from mere calculatory aspects to more specific contractual aspects. The boundary conditions of the construction object are to be included in the calculation. The employment of subcontractors is to be primarily legally assured. Devolution by the commissioner and construction site organization and management are in the center of the continuum and influence both sides. At some point, the quantified contract risks have to be included in the calculated price because they might otherwise lead to the rejection of the commission. Conversely, the prevention of certain cost-intensive items, which may arise during calculation, should be central topic of contract negotiations. At this point, the circle between the two outermost peripheral points (calculation and contract) is completed.[21)]

Moreover, questions concerning volume, price, deadline, soil and groundwater risks, inherited waste, archaeological finds etc. also play a pivotal role in the decision-making process of structural and civil engineering projects.

3.3.1.3 Construction risks

Four key areas should be considered with respect to risk assessment during the project realization, and hence construction, phase: Costs and activities, deadlines, quality as well as boundary conditions, and previous achievements. The following remarks include a pragmatic approach towards controlling and monitoring the realization of a constructional operation.[22)]

20) Cf. Jacob/Helbig (2000), pp. 19–26 for a detailed description.

21) Concerning the remarks on contract and calculation risks cf. ibidem, pp. 17–27.

22) Cf. Horchler (2000), pp. 28–36.

Before the construction begins, the following measures have to be taken:

- Familiarization with the construction contract and the related documents
- Identification of all participants involved with the construction project by the commissioner and their authorities
- Analysis of duties and previous achievements of all persons involved in the construction project
- Written documentation of deviations and report to the client
- Systematic work preparation including work calculation
- Planning of liquidity using the work calculation (task side) as well as the contractual payment side (proceeds side)
- Handover of the prepared project to the construction manager/foreman: Here, extensive explanations concerning the construction procedure planning, the separation into sectors, the material to be utilized, and the cost specifications are required

Controlling the construction project mainly includes a variance analysis concerning the costs, masses, quality, deadlines, timely delivery, and proper administration of the necessary plans and realization documents, as well as the miscellaneous contract duties. The deviation analysis is to be registered in writing. In case of third party negligence, the client is to be informed immediately, and must be notified about any additional charges in writing. Ultimately, construction project controlling and monitoring can be seen as an integrated approach.

3.3.1.4 Acquisition risks

Acquisition risks are closely tied to the underlying acquisition method. The risk-induced acquisition process method is closely tied to the establishment of a personal optimum vertical range of production. A company's vertical range of production that is too large binds more management and capital capacities than necessary. These are thus not sufficiently available for the actual core tasks of the company. At the same time, a dramatic delegation of core tasks to third parties may lead to the loss of the company's business basis.

The delegation to highly experienced subcontractors minimizes inefficiencies and the company's construction monitoring expenditures. However, the main contractor should keep two to three alternatives for each activity at hand, because otherwise it is in danger of being defenseless against unjustified price spikes caused by subcontractors over the course of time.

Furthermore, one should be aware of the legal difficulties of the work contract regarding delay, acceptance, post-construction work, warranty, and indemnification. The reversal of the burden of proof after acceptance of the activities executed by the subcontractor and the effective financial recourse to subcontractors for complications, e. g. contractual penalties and consequences of delay to the client, is particularly problematic. To minimize these potential damages for the main contractor in advance, subcontractors have to be thoroughly inspected for pre-selection prior to the definition and placement of tasks for the various engineering departments and subcontractors involved. Additionally, necessary high expenditures for monitoring the construction project should be expected to remain constant over the course of the project. Particularly, in order not to deviate from the time-critical scheduling framework of subcontractors, it is recommended that important tasks are distributed to at least two subcontractors to ensure that one is able to take over construction (and effectively employ additional resources) in case of the other's absence. Thus, delays should be minimized.

As a rule, subcontractors are not particularly financially strong companies and are able to only participate in the pre-financing of a project in a minor way. The goal of finance management, therefore, has to be to ensure liquidity with customer financing in the form of deposits or progress payments, as well as trade credits, and not to better pass along the terms of the client to the subcontractor. Besides, this rule also counts toward forwarding other contractual items such as acceptance terms, warranty deadlines, agreement and contract penalties, as well as performance rewards, for post-construction work. However, this request is legally constrained.[23] Securities of subcontractors exist to ensure financial coverage of the head contractor in the form of security deposits, bank guarantees or bond insurance policies.

3.3.2 Typical risk sharing in life-cycle valuations of construction projects

The following tables give an overview of the typical types of risks involved in the phases of life-cycle planning, realization, and operation and gives the usual contractual assignment of a construction project.[24]

Table 3.6 Design risks[25]

Types of risk	Description	Allocation		
		Client	Contr.	Shared
Failure of the design concept	The implementation of requirements of the client's design concept failed.		X	
Additional development design	Development of initial design according to the as agreed schedule and time frame. Failure normally leads to additional design and construction costs.		X	
Changes of client-side requirements	The client demands changes of design that incur additional costs.	X		
Changes of operator-side requirements	Operator-side design changes may incur additional costs.		X	

23) Cf. without author (1998), pp. 62–69.

24) Jacob / Kochendörfer (2000) pp. 141–144.

25) Ibidem.

Planning changes due to external influences	Changes due to new laws and regulations.	X		
Failure to implement design concept	Incorrect implementation of construction design during construction phase incurs additional costs.		X	

Table 3.7 Construction risks[26)]

Types of risk	Description	Allocation		
		Client	Contr.	Shared
Incorrect calculation	Calculated construction costs are erroneous		X	
Incorrect scheduling	Construction time exceeds expectations		X	
Unforeseen soil conditions	Unexpected inferior soil conditions may incur additional costs.			X[27)]
Unforeseen soil conditions under existing structures	Additional costs for the contractor due to existing construction conditions or unavailable soil analyses.	X		
Access to construction site delayed	A delay of the site access can cause a delay of the whole project.			X[28)]
Site protection issues	Theft or vandalism cause additional costs and delays.		X	
Responsibility for workplace safety	Accident prevention regulations have to be followed.		X	
Third-party demands	Applies to residential claims caused by damage to structures or loss of quality of living.		X	
Requirement of additional compensation	May hinder project realization and incur additional costs.			X
Claim of prolonged construction time	May hinder project realization and incur additional costs.			X
Force majeure	Force majeure (unforeseeable circumstances) may incur additional cost or render the investment unusable.			X

26) Jacob/Kochendörfer (2000) pp. 141–144.

Termination of contract due to force majeure	Contracted parties may not be able to carry out their services due to unforeseeable circumstances.			X
Specific changes of the legal framework	Changes of the legal framework involving the client and a change of its requirements may lead to a shift in costs.	X		
General changes of the legal framework	General changes of the legal framework may occur during the construction phase and may change costs and requirements.		X	
Changes in taxation	Changes in taxation may influence project costs.		X	
Changes of the VAT rate	Changes of the VAT (sales tax) rate may increase project costs. Value-added tax payments should be reimbursed.	X		
Other changes of the VAT rate.	Other changes of the value added tax, which do not affect the value added tax rate (e. g. taxable base).		X	
Insufficient project leadership	Insufficient project leadership may incur additional costs, e. g. due to poor coordination of subcontractors.		X	
Strikes by construction companies	Strikes by construction companies may extend construction time and cause additional costs.		X	
Erroneous time and cost planning with respect to outsourcing	Erroneously calculated costs and time schedules regarding aging of existing structures are part of client-side risks unless the contractor is the guilty party.	X		
Erroneous time and cost planning new construction commissions	Erroneous cost calculation for the commissioning of new structures may accrue more costs due to delays.		X	

27) Depending on circumstances.

28) Depending on circumstances.

Table 3.8 Operating risks

Types of risk	Description	Allocation		
		Client	Contr.	Shared
Running costs are higher than expected	The client must be financially liable for excess costs if the changes in running costs are commonly agreed upon. The contractual agreed price can be checked at regular intervals, if the conditions lead to increased operating costs and are outside of the control of the contractor.			X
Running costs are lower than expected	An adjustment of the contractual agreed price may be implemented, if the costs are significantly reduced and the conditions are outside the control of the contractor.			X
The contractor did not fulfil the agreed conditions and standards	The payments to the contractor are reduced. The contract can be cancelled if these standards are permanently not fulfilled. But the client has to pay compensation in this case.		X	
Termination of contract by the client without failure or non-fulfilment of the contractor	After expiry of the time limit, the client may terminate the contract at any time but has to pay damages to the contractors and their investors.	X		
Repairs after damage	The contractor is responsible for all losses and damages unless they are caused by the client.		X	
Insufficient maintenance	The contractor is obliged to pay for maintenance and repairs of the investment to keep it in a good condition. After expiry of the contract and after a defined period of time thereafter, the client may inspect the structure conditions regularly.		X	
Maintenance more expensive than expected	Maintenance costs significantly higher than expected due to factors outside the control of the contractor, may lead to, for example, a five-year revision of contractual prices.			X

Insurance	The contractors have to produce proof of insurance. If no insurance is available on the market, the client may decide whether the contractor may proceed without insurance coverage or not.		X	
Changes in costs due to changes of the legal environment	The contractor may demand adjustment of contractual prices due to changing laws or regulations. The client may demand a price adjustment for associated cost reductions.			X
Availability/provision	The contractor is only paid for work carried out.		X	
Improvement of technology	Both client and contractor may provide suggestions to adjust to changing security technology and share resulting savings.		X	
Rising interest rates increase costs for the contractor	The contractor must bear the risk of changing interest rates.		X	
Inflation increases costs for the contractor	The portion of the payments concerned with operating costs is annually adjusted to match the contractually agreed indices.			X
Cost increase due to changes of the taxation	Such a change is outside of the influence of the contractor and can have significant effects on the operating costs and the maintenance costs, e. g. they may lead to a five-year revision of the contract payments.			X

3.3.3 Cost accounting assessment of risks[29)]

The risks above are quantified in the pre-calculation and assess their probability of occurrence. With the aid of the scenario method, one can determine how individual risks jointly affect projects. By observing the general case, optimistic and pessimistic versions, a probability corridor for the pecuniary effect of combined risks can be determined.

The individual construction company may embrace particular chances, unlike its competition, by neatly dealing with the individual risks and the combined risks. This involves, in particular, recognizing, accepting, changing according to, diminishing,

29) Excerpted from Jacob/Winter/Stuhr (2008), p. 1109.

preventing, or refusing risks. Depending on the contract type, payment method, construction sector, type of calculation, scope of activities, difficulty level, and size class of the client, different risk classes of capital expenditure emerge. A stronger portfolio mentality could be beneficial and could reduce risk in general. Furthermore, a universal process owner in the construction team with oversight of the whole project, from calculation (pre-estimate) to acceptance and billing, would contribute to risk reduction.

3.3.4 Risk evaluation tools

A distinction can be made between quantifiable and unquantifiable risks. Quantifiable risks are measurable and may be evaluated on the basis of statistical figures or methods. The basic prerequisite for a meaningful quantification of risks is sufficient statistical data. Methods include, for example, correction methods, the Monte Carlo method, the "value at risk" concept, and sensitivity analysis. The sensitivity analysis is also applicable to unquantifiable and immeasurable risks, respectively. If a risk evaluation cannot be conducted using objective or subjective standards, indirect risk evaluation should be considered the standard fall-back option, which is employed, for example, for checklists or scoring models. Risk evaluation becomes more difficult in conjunction with unquantifiable risks becausein this case, emotions matter to a greater degree than statistical methods.

The following list shows a selection of risk evaluation tools:

– Correction method
– Monte-Carlo method
– Value at risk
– Sensitivity analysis
– Checklists or guidance systems
– Scoring

The correction method is used to consider uncertainty during data collection by means of risk add-ons and risk discounts.[30)] Risk discounts are assigned to deposits and risk add-ons are assigned to payoffs. Correction values may be applied to single or multiple pieces of data. After applying correctional information, the calculations are made with stable data. The advantage of this method is that it is simple and easy to use. However, corrections applied subjectively lead to the danger of "calculating it into the ground". Hence, interpretation of the target values and evaluation of the chances and risks are problematic. The results from this calculation method often seem pessimistic due to the consideration of uncertainty together with every influencing variable. Probabilities are not considered at all, and risks are considered globally, rather than individually, in this procedure. As a result, the correction technique may only be used as a rough reference.[31)]

30) For the correction techniques cf. e. g. Wolf / Runzheimer (2009).

31) Cf. Ibidem.

The objective of the *Monte-Carlo method* is to solve mathematical problems with simulations of random variables. The Monte-Carlo method, therefore, is a simulation method that serves to determine result distribution. This method permits simulation influenced by random factors. The advantage is the easy structure of the calculation algorithm. The experiments are conducted repeatedly and independently of one another; i. e. the simulation of the process is repeated as often as it takes to produce statistically reliable results. After innumerable simulation runs, the result distribution of the values changes less and less. The presentation of the statistical evaluation of the results of the separate runs can take place by means of a risk profile (arithmetic chart).

The Monte-Carlo method may, for instance, be meaningfully utilized through the computerized simulation of a construction process. The program @RISK[32] can, for example, simulate the influences of precipitation and temperature on the construction time of a concrete ceiling or a concrete street. To this end, weather data of respective regions from past decades is used. To illustrate, a sudden drop in temperature may potentially lead to a delay in the hardening of concrete and, consequently, to an increase in lost work days. In this case, rising costs can be expected; particularly, if the skilled workers involved in the process cannot perform any other tasks during that time, or the deadline cannot be met (contractual penalty).[33]

Value at risk (VAR) is the loss in the value of a portfolio over a given time period exceeded with a given (normally small) probability.[34] It is used as an information tool to provide the management with an indicator for market risks. In the banking sector it is used to report risk, to internally appropriate capital, and for performance assessment.

For the calculation of VAR, it is necessary to determine the following prerequisites:[35]

- Creation of the portfolio to be analyzed (a portfolio, in general, is an outline of financial instruments such as, for example, the combination of credits),
- Identification of market parameters , i. e. the quantities observable on the market that influence the value of the portfolio (interest rates) and establishment of a functional relation that reflects the change of the portfolio value depending on the change of the market parameters.
- Definition of an observation period (for an estimation of the parameters of the assumed distribution)
- Establishment of liquidation / holding time
- Establishment of a probability level

After defining the prerequisites, VAR can be calculated using different algorithms – e. g. the correlation approach, historical simulation, or the Monte-Carlo method.

In a *sensitivity analysis*, the effects of changing variables (e. g. price, quantity of sales, investment sum) on the results (e. g. capital value) are demonstrated.[36] This analysis

32) @RISK is a software program developed by the company Palisade. It is used for the analysis of risk and uncertainty.

33) For a deeper discussion on the Monte-Carlo method refer to e. g. Liu (2008).

34) Cf. Duffie / Pan (1997), p. 7.

35) Cf. e. g. Jendruschewitz (2003).

36) For sensitivity analysis cf. e. g. Wolf / Runzheimer (2009) and the literature they refer to.

answers the question as to what extent input variables can be varied without the fixed target value exceeding or falling below a fixed value. The sensitivity analysis of the respective construction processes is the premise for reliable disturbance recognition. In the sensitivity analysis, a distinction can be made between the method of critical values and alternative calculation.

Regarding the method of critical values, the maximum derivation of one or more variables is determined without threatening the fixed output figure. Values that are considered to be uncertain and their correlation are reproduced in a capital value function. Solving the capital value equation will yield the deviation wanted.

The alternative calculation expresses the stability of the decision criterion if one or more values change according to the specifications. The values that are considered to be uncertain and their correlation once again are presented as a capital value function. The effects of the differences, the influencing variables display between the initial value and the capital value indicate their stability.

The disadvantage of the stability analysis is the fact that it often depends on one influencing variable only with the effect that uncertainty cannot be realistically included. The missing probability distribution of the influencing variables results in incalculable uncertainty. However, a high transparency with respect to uncertainty can be reached.

Checklists serve to prevent incorrect information and to reduce paucity of information. Generally, they have the appearance of operational and procedural instructions and contain a list of possible causes and effects of disturbance. Checklists are offered by various institutions, but they need to match the requirements of the specific company.[37] With the aid of checklists, the suitability of a subcontractor for a certain task may be determined. This is particularly advisable for first-time commissioning of companies or if insufficient information about the operating principles of the respective company are available.

Another instrument to estimate unquantifiable risks besides checklists is *scoring*. Credit scoring is a point-assignment method for making a prognosis about the creditworthiness of customers. This procedure may be employed for new clients as well as registered clients. For registered clients, previous entrepreneurial behavior is analyzed. A mathematical variance analysis supports disclosure of hidden correlations between internal and external data and past bad debts. The acquired data is used to create a score table. Thus, point values emerge for every token that yields a score. The smaller the score, the higher the probability of new bad debt. This method simplifies the decision-making process with respect to acceptance or refusal of a client.[38]

3.3.5 Risk transfer

Risk may be transferred with or without insurance. *Insurance* can be defined as a package of passive indirect actions which works as financial coverage against potential

37) Cf. Zellmer (1990), p. 34.

38) Christianus (2000), pp. 92–94.

damage.[39] Transferring risks with insurance is the safest but also the most expensive method. Risk, in this case, becomes clearly calculable in terms of costs in the form of insurance premiums. As insurers rate the construction business as highly vulnerable to damage, premiums peak accordingly.

Some of the most important types of insurance are property insurance, revenue insurance, general indemnity insurance, additional insurance (e. g. recall insurance), and Hermes insurance.[40] Insurance merely covers loss of asset risks, but not merchandising or production risks. These risks, for example, could be redistributed via factoring or outsourcing. Factoring is the transfer of bad-debt risk to a factoring company. If a factoring company is willing to buy a claim without recourse (forfaiting), the bad debt risk of this claim is, in general, transferred to the purchaser; the vendor is paid off up to 90 % of the claim. This method is particularly advisable where only small amounts of equity capital or insufficient information about the credit history of the client are available.

Outsourcing means redistributing added value activities of a company towards suppliers or subcontractors. Thusly, respective risks are also transferred. The amount of risk transferred is crucially dependent on the negotiation skills of the contract partners as, during negotiations, new interaction risks may emerge.[41]

3.4 Features of joint ventures

3.4.1 Basics

In the construction industry, a joint venture (JV) is defined as a union of two or more independent companies, which form a temporary partnership and are contractually committed to perform a given work order together. Furthermore, participating companies provide required quantities of materials and quality of activities in a timely fashion within the contractual framework.[42] Usually, in such joint ventures, a civil partnership is created to act as an outside company in accordance with the civil code of German constitutional law. In contractual relationships with a client, this company acts as third party with total partnership asset control. The shareholders are jointly liable to the client for fulfillment of the activities described in the contract.

In Germany, there are two kinds of JVs:[43] The normal or production JV (in German “Leistungs-ARGE”) and the holding JV (in German “Dach-ARGE”). Both forms are equal with respect to the relationship with the client (external relations), whereas the difference is found in their internal relationship structure of involved companies. In a normal JV, the collaborative work is performed at JV level. The contribution requirements of the shareholders - in accordance with the internal relation agreements - dic-

39) Bauch (1994), p. 67.

40) For a deeper discussion on the topic “Insurance in the construction business”, the authors recommend Wahner et. al. (2008), pp. 1195–1287.

41) Cf. Bitz (2000), p. 49 ff.

42) Cf. also Burchardt (2008).

43) Cf. also Jacob (ed.) (2009), p. 20 ff.

tate the provision of funds, staff, equipment, materials, and other services. In comparison, shareholders in holding JVs do not perform collaboratively at JV level. Thus, provision requirements are not prerequisite for holding JVs where total performance is divided into individual tasks, which are executed by their own shareholders. The joint venture shareholders perform their tasks independently and autonomously with separate subcontracts. Therefore, the individual shareholders have three responsibilities:

– They are the contractor for the client
– They operate as a client to the subcontractor
– The shareholders assume the role of contractor for independent work performance taken over through the signing of a subcontractor agreement

The Federation of German Construction Industry[44] offers standard contracts for normal JVs and holding JVs for the purpose of construction work only. For very simple construction projects, a standard contract is issued by the German Construction Federation (in German "Zentralverband des Deutschen Baugewerbes"). There is also a joint-venture standard contract available from the Federal Association of Consulting Engineers (in German "Bundesverband Beratender Ingenieure") for design JV projects. In cooperation with all major associations (among them the German Chamber of Architects, Federal Association of Consulting Engineers, German Construction Federation, Construction Industry Association Lower Saxony-Bremen), a standard contract for holding JVs in the fields of joint design and construction was recently developed. The joint venture is directly preceded by the bidding consortium, which was created with the aim of preparing a joint offer and awarding contracts from clients. In this case, the bidding consortium is automatically converted into the JV when the contract has been awarded.[45]

3.4.1.1 Normal joint venture

Shareholder activities are divided into provisions (activities of shareholders **for** the joint venture), billable third-party services (activities of shareholders **to** the joint venture), and outlays (activities of shareholders provided in place of the JV).

Involved shareholders do not provide all essential activities as a corporate contribution payment but as third-party services. They are paid exclusively using the principle of cost coverage. The JV contract defines quality and quantity of provision obligations. Schedules and the amount of rendered services are specified later by a supervisory authority comprised of shareholders.

Usually, financing requirements are limited to pre-financing of construction activities, the amount of which is typically small as the JV receives monies mostly in the form of down payments during the construction period. The funds needed for the pre-financing payments are provided by shareholder payments, debt financing by banks, and eventually by client pre-payments to the JV.

44) In German "Hauptverband der Deutschen Bauindustrie".

45) Cf. Jacob (2009).

Required project staff may be delegated or released by shareholders or employed directly by the joint venture. In general, provision requirements are equally distributed through a shareholding ratio. Staff is frequently transferred from the involved companies to the JV.

The procurement of materials should be based on market requirements. For example, the necessary materials are purchased on a competitive basis either from third parties or from the shareholders. The latter case is handled as billable third-party business directly linked to project expenses, which cannot be equalized through account adjustments. Following a decision by the supervisory authority, materials used can also be provided by the shareholders at the price specified in the construction equipment and tool list (in German “BAL” - Baustellenausstattungs- und Werkzeugliste). The payment of bills from the shareholders is allocated within the framework of account adjustments.

The shareholders decide on the appropriate time, scope, and duration of equipment procurement. It may be organized either on the basis of an already completed rental agreement for billable third-party business, through the purchase of equipment from third parties / shareholders, or by renting externally from third parties on a competitive basis.

Clients receive down payment bills from the JV in accordance with the percentage of completion. Billing of partial activities rendered by shareholders is done on a monthly basis using billing rates of the JV. In case of lacking liquidity, the shareholders are liable to contribute. Profits should normally be distributed to the shareholders only at the end of a construction project. If profit distribution occurs earlier, a mandatory bond is required by the respective shareholder. JV losses can be compensated by nonpayment of shareholder bills.

3.4.1.2 Holding joint venture

In this type of JV, each shareholder is responsible for their subcontractors’ agreed upon share of workload required for project completition. Depending on the industry sector, staff, equipment, materials, and subcontractors are coordinated by the respective shareholders. Expenses or compensation for JV management are usually not provided.

The shareholders issue bills to the JV for their completed work. The sum of those bills results in the final bill of the JV to the client. Down payments provided by the client are forwarded directly to the shareholders according to the respective individual bills. Therefore this is no direct financial stream to the JV. In turn, should client payments not cover the full amount specified in the JV bill, deficits are passed on to the respective shareholder. Since the performance and compensation risk are adopted by individual shareholders, the profit and loss realization stays there.

3.4.2 Characteristics of the estimating process

The basic agreements that are of equal significance for the calculation process are declared in the JV contract. They include, for example, fixed rates for construction management, foremen, technical and business management, determined rates for wages, equipment, and so forth. Guarantors for contract activities and liability guarantees need to be determined, and insurance issues should also be considered.

3.4.2.1 Securities

A joint venture can regularly choose, between various securities, according to the construction contract. These are provided by the JV to the client to ensure project completion and defect liability claims.[46] According to the German Construction Contract Procedures for the Realization of Public Construction Projects (German VOB/B), deduction or deposition of funds as well as bonds may thus come into consideration unless involved parties stipulate otherwise in the contract. Most commonly, in practice, bonds are agreed upon. Depending on the purpose of individual securities, a distinction is made between different types of bonds. The *performance bond* basically covers the fulfillment obligation of the contractor until the construction is accepted. The *warranty bond* provides protection from liability claims due to defects in the final construction after acceptance. The *performance bond* protects from performance and defect claims and refers to the working result. Also, an *advance payment bond* may be required in case financial compensation or advance payments were made prior to the start of the construction work.[47] The *bond for down payments* for material and components ensures the client against contractor claims for compensation for incomplete activities.

In addition to external bonds, there are bonds that a shareholder has to provide to the other JV shareholders (internal bonds). Back bonds, then, are employed by shareholders to safeguard against internal risks associated with the JV (e.g. outage of a shareholder). If it comes to disbursement of available funds to shareholders, individual shareholders may be asked to provide a bond, as security, equivalent to the amount paid out to them (bond for interim distributions). If work is carried out by shareholders as subcontractors, appropriate bonds (e.g. performance bonds) should be provided. Lastly, other partner bonds may be considered.

46) Extracted from Jacob (ed.) (2009), pp. 47–49.

47) Cf. Wahner et al. (2008), p. 1247.

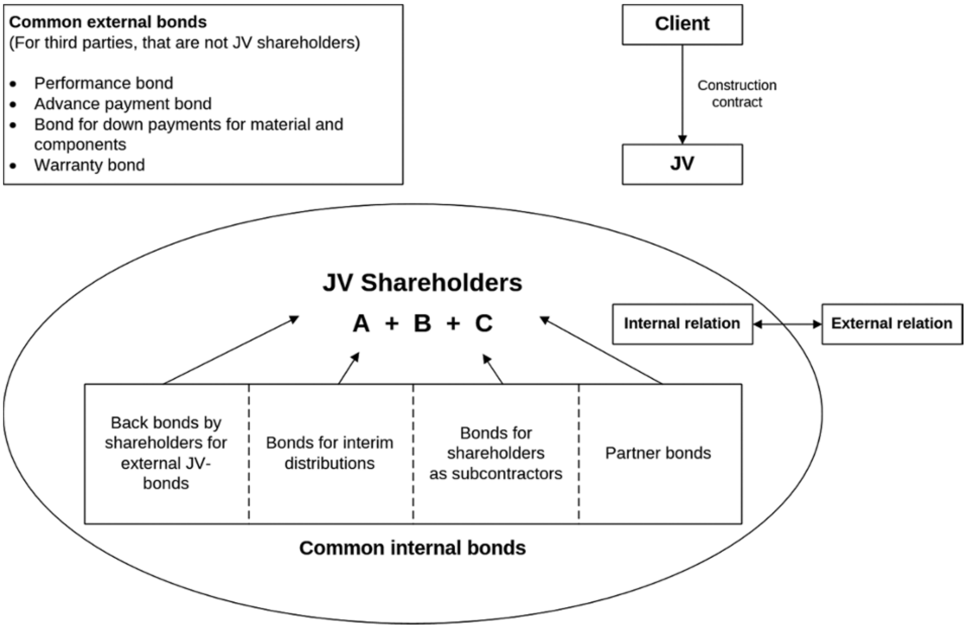

Figure 3.7 JV bonds[48)]

3.4.2.2 Joint liability

Each JV partner is jointly liable not only for their own activities but also for the activities of other JV members. This is particularly important if activities are realized poorly or if a JV partner declares insolvency. This kind of disturbance in delivery and performance can have an effect on the construction period as well as the later period of defect claims. However, it is possible to partially safeguard via provision of bonds or conclusion of specific insurances.

3.4.2.3 Insurance

Construction liability insurance

The object of construction liability insurance is to protect the contractor against financial loss, which may arise from the statutory liability associated with construction management. In order to obtain compensation for third-party damages through an insurance, a damage claim has to be filed. Hence, damages caused by the contractor are not covered by this kind of insurance. Liability insurance is a type of insurance that covers people, property or resulting financial loss. It is optional and is has no intention to pay, but to dispense from the claims of the damaged third party.[49)]

48) Cf. Burchardt (2009).

49) Cf. Wahner et al. (2008), p. 1205.

Construction companies, which are commonly involved in joint ventures, are covered by their completed-construction liability insurance, even without special agreements, when participating in JV projects. Each JV partner is insured in accordance with their share of the JV up to the agreed amount of coverage level stipulated in their construction-liability insurance contract.

If a shareholder ceases to be a member of the JV, the remaining shareholders are liable to fulfill the contractual activities. They have to provide the remaining activities of the former shareholder for the respective construction site and, if necessary, have to take on the additional insurance costs.

The JV may also take out construction liability insurance if the shareholders agree, and the adoption of costs is regulated. Thus even in cases where a shareholder ceases their JV operations, insurance cover is provided for the total performance.[50)] This is particularly recommended for construction projects of a certain size within a JV.[51)] In such cases, the most deciding factor is a cost comparison of individual insurance policies assuming costs for total coverage.

Construction performance insurance and other insurances
As the contractor is responsible for the accurate realization of their construction activities until acceptance of the finished construction by the client and since construction activities are exposed to various risks, some of them should be covered by construction performance insurance. Thus, any risks that may occur due to unforeseen damage to or destruction of the construction performance are protected against. However, construction performance insurance covers only property and does not cover staff, or financial loss. It includes construction activities (delivery and rendered services) of new constructions as well as renovations, and investments into related surrounding structures.

Insurance for additional interest for construction companies include, for example, environmental liability insurance, environmental damage insurance, and construction equipment insurance.

Additional acquisition and processing costs
Usually, each JV partner bears its own costs during the acquisition phase, which may lead to additional overhead costs owed to consultation of external professionals (e.g. lawyers, consultants, engineers, and cost experts). These additional costs have to also be defrayed in the event of an unsuccessful acquisition.

If the acquisition is successful, the JV is subject to additional leadership charges. Moreover, provided joint-venture billing rates are employed to calculate costs for staff and equipment, which may differ from the costs of own construction sites. All these considerations should be adequately reflected in the calculation.

50) Cf. Wallau/Stephan (1999), p. 99.

51) Cf. Wahner et al. (2008), p. 1203.

3.5 Using estimating software

3.5.1 Objectives and benefits

In heavy construction, the procurement process is subject to anumber of different constraints and conditions. Commonly, the time available for processing bids is particularly short. Nonetheless, quality requirements when determining bid prices are disproportionately high in order to generate an adequate construction result for acquired contracts. Moreover, 90 % of bids are not successful. They are, figuratively speaking, created to be discarded, which makes the situation all the more difficult.

With these issues in mind, the question of how EDP software can help support the process arises.

The structure and level of differentiation (of bids) need to be of significant quality for the calculation to effectively support the contract-acquisition process. It is the foundation for later work estimates, which, in turn, constitute the basis for an objective-oriented construction site monitoring. This sort of quality requirement is most efficiently realized through a customized master data calculation, which has been a tried and tested method with the following objectives:

- To assist contract acquisition
- To constitute a secure foundation to make bid decisions on business grounds
- To be a basis for the successful implementation of extra work and claims
- To constitute a foundation for result-oriented monitoring of construction sites (site monitoring)

This chapter, therefore, is intended to illustrate the objectives and benefits of EDP-supported bid calculation.

3.5.2 Recourse to master data

During the bid calculation process, client-side items listed in the specifications are used for the computation of economic bids. Functional bids that do not contain a bill of quantities have to be supplemented with the same by the contractor using provided bid documents. Expected costs for wages, materials, equipment, subcontracts, and other costs must be included in the calculation during the procurement process with values that reflect actual requirements as closely as possible. A regular, differentiated calculation lists individual activities separately. For example, formwork, reinforcement, and concreting.

Calculation data is basically differentiated into standard data and individual cost estimates. Calculation master data includes required information readily available and can be used for comparison (i. e. recourse) as follows:

1. Search and selection of a similar standard item; e. g. foundation concrete
2. Customization of specific cost estimates; e. g. material costs for concrete that are specific to the region

EDP support proceeds as follows:

– The task cost estimator selects the current item on the screen
– Using a selection template, the estimator searches in the standard project for a standard item closely similar to his own and inserts it via “drag and drop”.
– The selected standard item appears on the screen and allows the estimator to make the required, project-specific adjustments, e. g.:
  – Input of expected excavation rate in accordance with documented soil conditions
  – Input of region-specific material costs for concrete

The following screenshot shows the standard item “concrete foundation.” The EDP-supported master data calculation is performed as follows:

– Task: Calculation of a concrete foundation
– Search in standard project: Estimator finds similar item in standard project; see following figure:

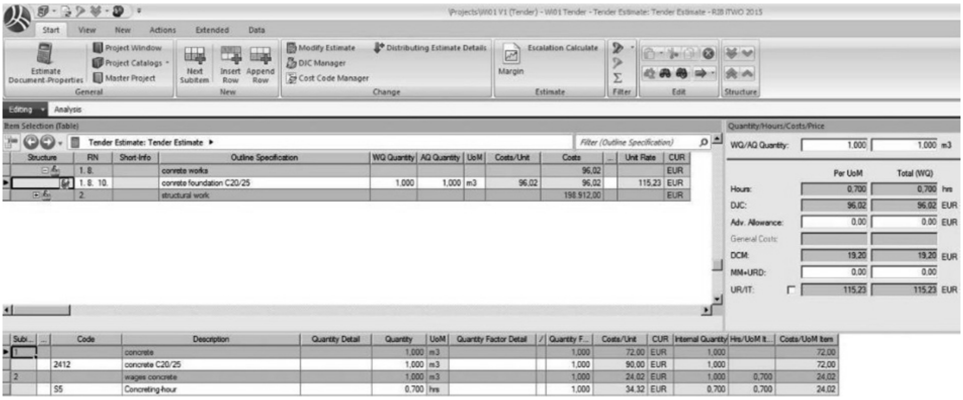

Figure 3.8 Standard item – Concrete foundation (RIB iTWO®)

– Insertion of standard item: Estimator inserts the standard item above
– Customization: The estimator adjusts required parameters as follows:
  – Costs for concrete are increased to 90 EUR / m³
  – The rate of concreting is increased to 0.8 h / m³ due to obstacles

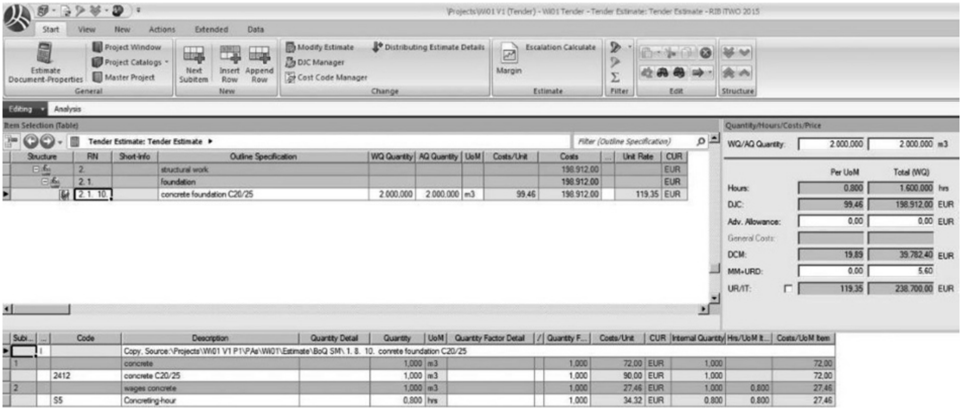

Figure 3.9 Calculation of item 2.1.10 – Concrete foundation (RIB iTWO®)

3.5.3 EDP evaluation

Due to the recourse to pre-structured, differentiated calculation master data, the estimator is now in possession of relevant and significant evaluations. Not only is the sum of calculated work hours available, but the data can also be sorted by hours and rates required for formwork, reinforcement, and concreting. In the field of civil engineering, calculations are performed with equipment modules, which contain individual consumption rates of diesel fuel, thus enabling an evaluation of diesel consumption for the project. The following list shows quantities and cost rates of calculated cost elements.

Table 3.9 Costs analysis

Item	Quantity	Unit	EUR/Unit	Costs in EUR
Concreting hours	1,084.00	h	34.32	37,202.88
Concrete C20/25	915.00	m³	90.00	82,350.00
Caterpillar 140 kW	420.00	h	45.00	18,900.00

The EDP evaluations also help the estimator with ABC analysis. The list “key items” shows sorted items by total price. Given the relevant parameters, the list shows the most cost-intensive items only, which constitute 80 % of the bid sum. Thus, this is a valuable checklist for the estimator to critically analyze the expensive items in order to ascertain if selected master data calculation approaches were adjusted towards project-specific cost estimates; see the following example:

Table 3.10 List of key items

Sum of bids: 7,750,240.00 EUR

Item	Quantity	Unit	EUR/ Unit	Costs in EUR	Percentage of total costs
1.8.10 Concrete foundation installing	12,000.00	m³	124.83	1,497,960.00	19.3%
1.7.10 Soil loosening and installing	120,000.00	m³	9.25	1,110,000.00	14.3%
1.9.17 Pipeline concrete DN300	28,000.00	m³	31.63	885,640.00	11.4%
…. …….	……	…	…….	……	….

The quality of the calculation, with respect to both differentiation of cost elements and close-to-actual cost estimates, is enhanced by master data support. The list "concreting costs" shows a detailed bid calculation and is filed with the public client before construction begins. This list is also the calculatory basis for potential post-construction work.

Table 3.11 Concreting costs

Item		Quantity	Unit			Total Unit price
1.8.10	Concrete foundation installing	12,000.00	m³			136.82 €/m³
		Quantity	*Unit*	*EUR/ Unit*	*EUR/Unit*	
	Concrete C20/25	1.00	m³	90.00	90.00	
	Concreting work hours	0.70	h	34.32	24.02	
	Sum Overhead costs 20 % Total unit price				114.02 22.80 **136.82**	

3.5.4 Master data organization

The master data requires a high degree of differentiation, division into operational/manufacturing processes, and comprehensive memory of prototypes for essential individual activities.

Master data should be consistently adjusted for the sections bid calculation, work scheduling, and site monitoring. Practice-oriented recourse to master data enables an economical estimating.

The basis for the total field of master data organization is constituted by the smallest information-bearing unit – called the cost element. In practice, master data memory consists of 5,000 to 10,000 cost elements, which are structured by high-level criteria in the calculation such as wages, materials, subcontractor works, and other costs. Wage-cost elements are structured by main fields of operation, and material costs should be structured in conjunction with their purchase costs. In the calculation, a large part is occupied by material cost elements and related cost rates. Figure 3.10 shows the structured cost-element hierarchy using three example material cost elements for different concrete goods.

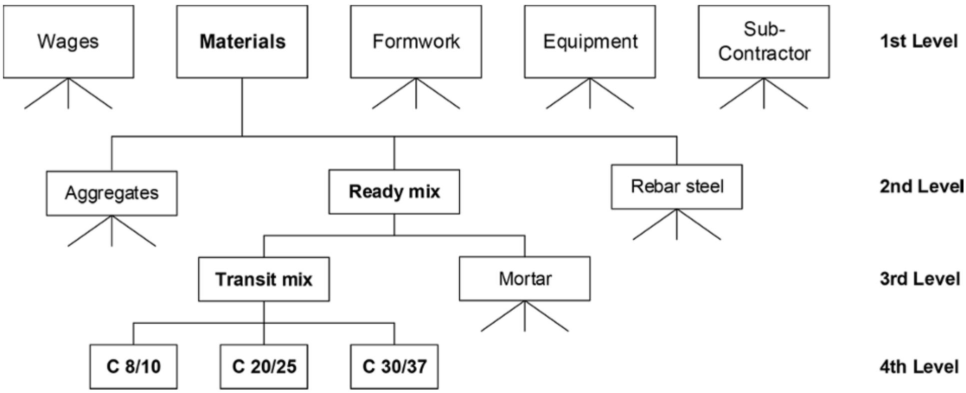

Figure 3.10 Cost-element hierarchy – Excerpt of concrete cost elements

In practice, company master data contains 5,000 to 6,000 material cost elements with fixed cost rates. Price levels of materials are memorized and allocated to region-specific market areas. Material costs, however, have to be adjusted for individual projects.

Wage cost elements are also itemized in the hierarchy. Commonly, they are structured according to fields of operation and union-rate groups respectively, for example:

- Wage cost element: Construction site setup
- Wage cost element: Excavations / earthworks
- Wage cost element: Concreting
- Wage cost element: Asphalt works
- Wage cost element: Piping works

Wage costs are usually determined using an average-wage value for the scheduled construction team meaning the same average wage is allocated to every wage cost element. The benefit of structuring different wage cost elements is that a differentiated evaluation of wage-hour sums can be performed. Hence, the estimator receives detailed information on wage-hour sums for individual operational fields, such as concreting and asphalt works, in addition to the total wage-hour sum.

Bid calculations are usually extremely pressed for time. Hence, it seems only natural to summarize or condense cost elements. The next level where items can be and are condensed is occupied by modules, which are noted in itemizations as equipment modules, in which individual cost elements, such as depreciation / interest, maintenance, fuel, lubricants, and operator wage costs are summarized in a single module. Cost rates have to be adjusted in accordance with equipment management.

The estimator can use these modules to receive any relevant detailed information in order to, for example, evaluate diesel consumption for a construction project.

Module: Excavator

Module:	**R 916**
Descr.:	**Crawler excavator with backhoe**

D+I – Depreciation and interest	Equipment
MNT – Maintenance	Equipment
Fuel + Lubricants	Material
Operator	Wage

Figure 3.11 Module – Crawler excavator

The superordinated hierarchy level is occupied by standard items where partial activities are calculated fully. The estimator can use standard-item values as recourse parameters and adjust them according to present project conditions. A tried and tested way to successfully perform master data calculations is to condense master data with the related detailed information to complete work packages - i. e. standard items. Using this method, it is important to note that a register of as few as possible but universally applicable standard items should be created so as not to bloat it unnecessarily.

Bid calculations are thus supported by master data in a significant way. The crucial part is to include all representative prototypes from the whole spectrum of processed categories in the standard calculation and, again, create prototypes in such a way that they are as universally applicable as possible so that project-specific adjustments can be performed with relative ease. In summary, standard items should exhibit the following features:

– Structure, if possible, should follow single cost-relevant criterium
– Clear assumptions for calculation
– Transparent calculation approach
– Interim calculations (e. g. for individual activities)
– Conversion factors to enable speedy adjustments
– Universal applicability

Figure 3.12 shows a standard item which includes the activites “formwork” and “concreting” with calculatory experience values. After data retrieval of this standard item, project-specific values, such as regional prices for concrete, have to be adjusted accordingly.

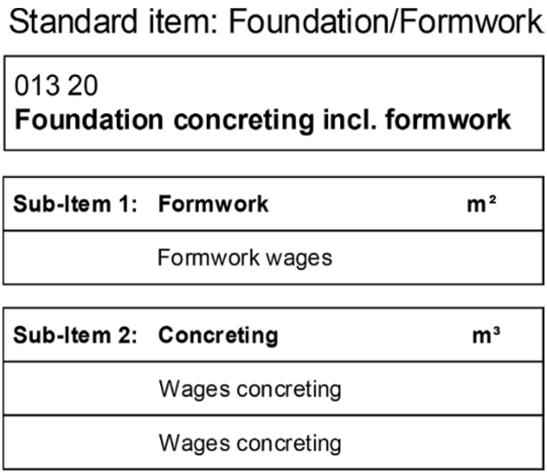

Figure 3.12 Standard item – Foundation incl. formwork

In principle, a universal standard project can be created that contains all relevant partial activities of processed bids. In some cases, it may be beneficial for faster access to create specific standard projects, like for bridge construction. Figure 3.13 shows a possible structure of standard projects. Employing this kind of data hierarchy enables swift access and retrieval of standard items such as bridge abutments in the respective standard project "bridge construction".

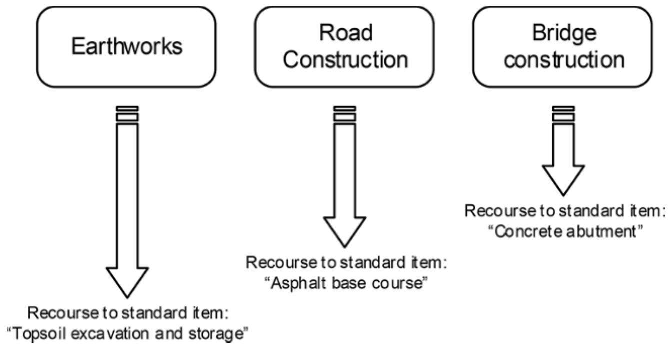

Figure 3.13 Standard projects – Structure

After a certain introductory phase for calculations supported by master data, the question remains how desired standard projects can be created. Several possible options are available. For one, universally applicable standard items can be created through company know-how; which, however, requires work hours outside the day-to-day operations. A more flexible approach is to integrate suitable items into the standard project using past bid calculations from the company files.

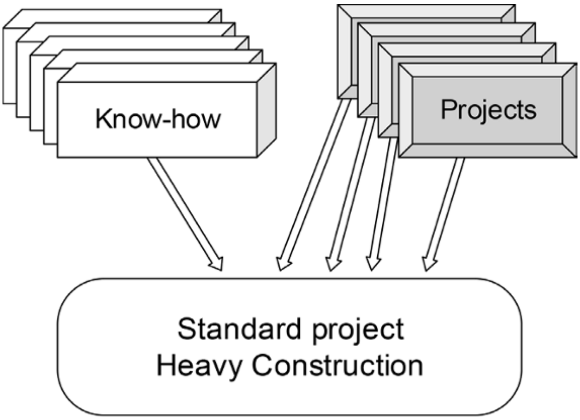

Figure 3.14 Creation of a standard project

3.5.5 EDP master data

The following example illustrates master data in conjunction with EDP software by RIB iTWO®:

Cost elements are the smallest information-bearing units, and the cost-element hierarchy is divided into different levels. The main cost element, "materials", occupies the first level and contains subdivisions for different material groupings, such as bulk materials, concrete, rebar steel, etc. It is recommended to create specified entries for materials and their relevant cost rates at root level. This enables both, access to concrete material cost elements, and later adjustments during the calculation phase as the cost-element hierarchy ensures swift customizations. The estimator has the following adjustments through cost factors at hand:

– Deduction rates on material costs total
– Individual deduction rates for the material group "concrete"
– Individual deduction rates for specific concrete goods

Figure 3.15 shows selected material cost elements for concrete.

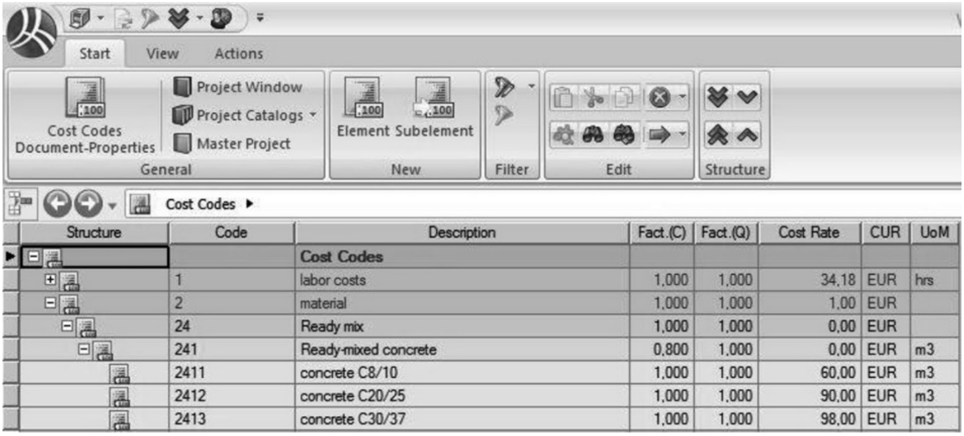

Figure 3.15 Material cost elements – Concrete

Modules are used primarily for equipment calculations. A module calculation for one excavator with an operational weight of 30 t and the related individual cost elements depreciation / interest, maintenance, diesel, and operator is shown in the following.

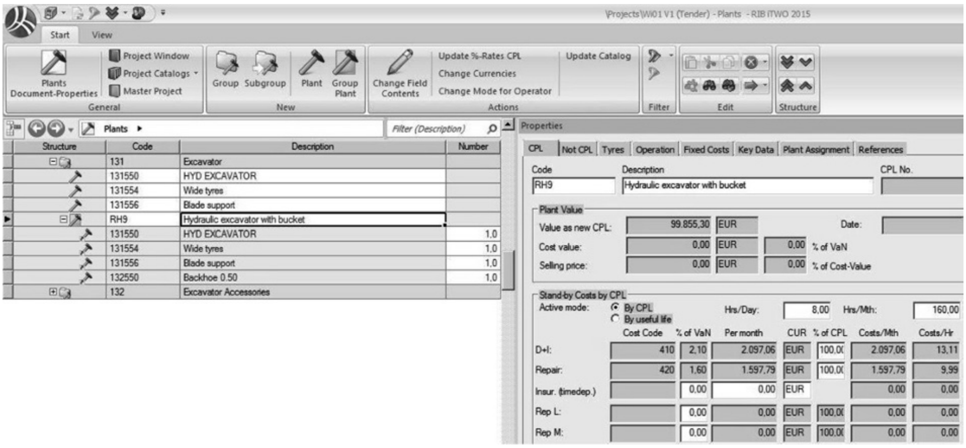

Figure 3.16 Equipment module – Hydraulic excavator

As stated previously, the standard position is the most condensed master data element in the hierarchy. The following figure shows the standard position “topsoil excavation and storage”, which contains the primarily required activities:

– Material removal + storage
– Material transportation
– Material separation
– Making material heaps and creating profiles

Figure 3.17 shows the electronic calculation of the required equipment and related performance values.

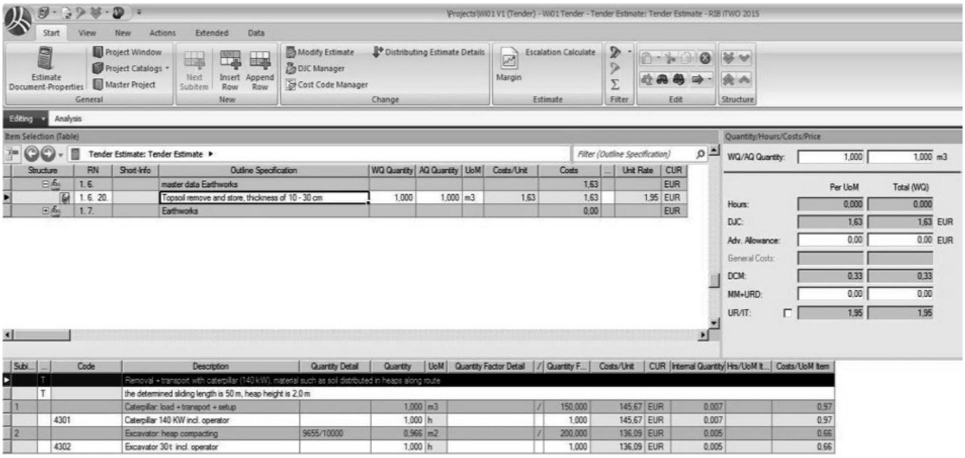

Figure 3.17 Standard item – Topsoil excavation and storage

3.5.6 Example – Topsoil excavation and storage

For the example hereafter, the following activities are required:

- Material removal + storage
- Material transportation
- Material separation
- Making material heaps and creating profiles

The estimator uses a suitable standard item and adjusts related calculatory approaches:

- Caterpillar performance rate: **100 m³/h** - the standard-item value was 150 m³/h. Since the actual transport distance is higher than the standard-item value, the estimator adjusts performance rate to 100 m³/h
- Excavator performance rate: **150 m²/h** - the standard-item value was 200 m²/h. Since present soil conditions show low rock content, the estimator adjusts performance to 150 m²/h

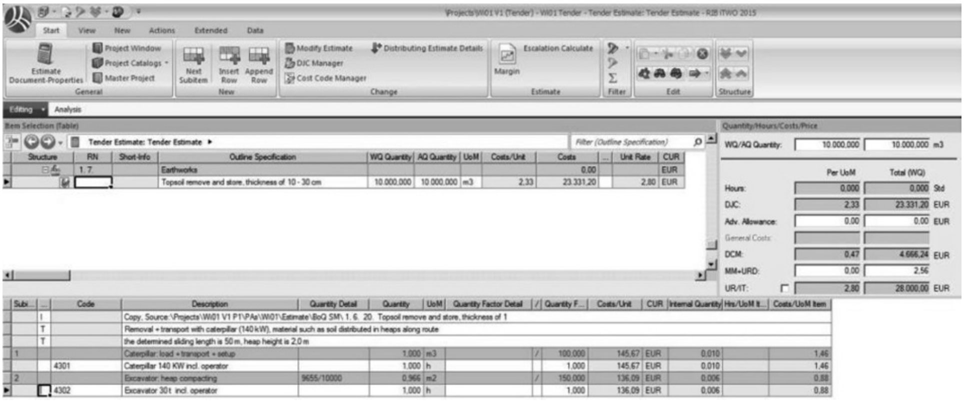

Figure 3.18 Calculation of item 1.7.10 – Topsoil excavation and storage

3.5.7 Example – Soil excavation and integration

For the example hereafter, the following activities are required:

- Excavation and loading of material according to profile
- Transporting material to designated reintegration site
- Reintegration and compacting of material according to profile
- Creation of planum layer

The estimator uses a suitable standard item and adjusts related calculatory approaches:

- Excavator performance rate: 250 m³/h - standard-item value was 300 m³/h. According to soil analysis, low rock content is expected, so the estimator adjusts the value to 250 m³/h
- Transport costs: 3.60 EUR/m³ - standard-item value was 5.00 EUR/m³. The estimator performed a detailed calculation and retrieved an adjusted value of 3.60 EUR/m³ due to an average transport distance of 5,000 m in the construction area

3.5.8 Approaching the market price

Bid calculations are usually performed under competitive conditions. The process begins with the estimator calculating a cost-covering bid price, which is usually higher than the current estimated market price. This means that the company has to bid below the going market price in order to increase the likelihood of becoming the most competitive bidder.

The company, therefore, is forced to explore opportunities to increase cost efficiency. Here, EDP-supported calculations can provide the crucial difference, the process of which is as follows:

1. Make calculations for individual operational fields through standard items found in the respective standard project
2. Make calculations for construction-site overhead costs using standard checklists

3. Perform analysis of first-draft calculation by evaluating most significant values: Quantities and costs of cost-element hierarchy, ABC analysis in accordance with cost elements and key items, purchase list, equipment list
4. Make adjustments specific to individual cost elements, e. g.: project-specific average wages, concrete prices, percentages of rented equipment and equipment maintenance, etc.
5. Make item-specific project adjustments: Performance factors (e. g. floor-slab formwork), performance rates (e. g. excavation rate), subcontractor rates, etc.
6. Perform a break-even calculation, i. e. determine the cost-covering bid sum
7. Approach the market price:
   - Attempt fixed-rate adjustments of certain processes, e. g. use formwork or floor-slab formwork only
   - Attempt fixed-rate adjustments of costs, e. g. a 10-percent deduction for transit-mix concrete
8. Determine competitive bid sum

When approaching the market price, cost reductions for material purchases can be calculated with the help of EDP software in an initial step. In the following example, a deduction of 20 % is assumed for all concrete goods under the item "transit-mix concrete", which is realized by input of a cost factor of 0.80 in the entry for the cost element "transit-mix concrete":

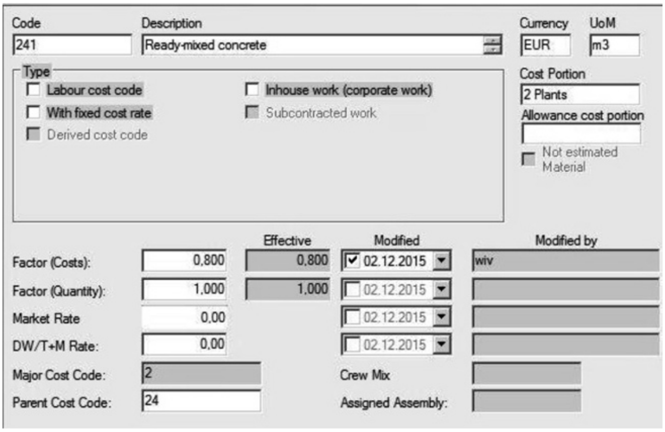

Figure 3.19 Deduction on material costs for ready-mixed concrete (cost factor)

Wage costs may also be subject to certain reductions. For example, using a more efficient formwork system can save wage hours. The following example assumes a 10 percent reduction for the wage cost element "formwork", which is realized by input of a quantity factor of 0.90 in the entry for the cost element "wages formwork".

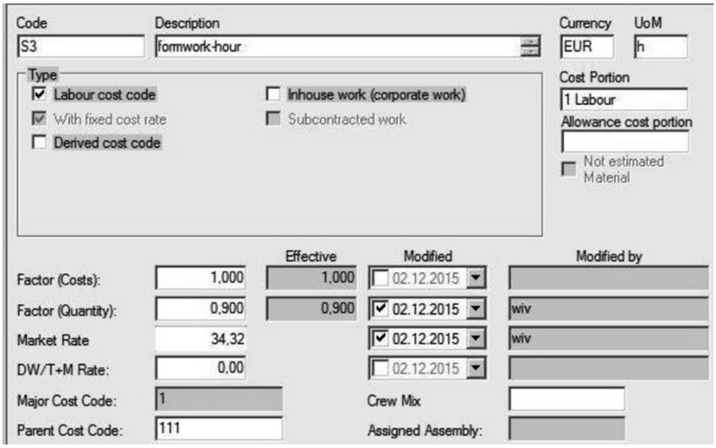

Figure 3.20 Reductions for wage cost element – Formwork (quantity factor)

The development of an alternative bid is one of the most effective methods to reduce costs. For example, using precast concrete elements in bridge constructions can significantly reduce time required for the construction and save costs. To this end, an individual project variant (called, for example, "precast concrete elements") can be created with the EDP software by adopting the unaltered calculations for earthworks and adding the relevant performance items for concreting, which are then modified accordingly.

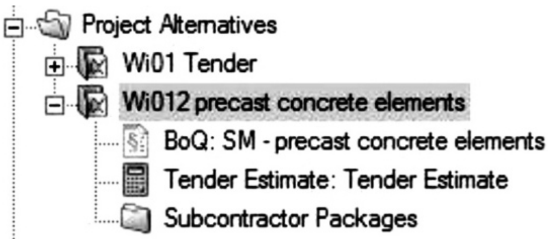

Figure 3.21 Project variant – Precast concrete elements

3.5.9 Summary and conclusion

The period between call for bids and bid submissions is brief, to say the least. Hence, companies are pressed for time when it comes to processing and preparing bids and bids. Nevertheless, quality requirements for bid calculations are crucial in order to effectively support the contract acquisition process. A realization oriented bid calculation is the foundation for later project monitoring.

These requirements can be met only through effective EDP support, and the most tried and tested approach in this case has been the master-data calculation method, the objectives of which are:

- To assist contract acquisition
- To constitute a secure foundation to make bid decisions on business grounds
- To be a basis for the successful implementation of extra work and claims
- To constitute a foundation for result-oriented monitoring of construction sites (project controlling)

References

Adenauer, P. (2005). *Ergebnisoptimierung durch FOKUS und Verringerung der Wertschöpfungstiefe*. In: Zentralverband des Deutschen Baugewerbes / Betriebswirtschaftliches Institut der Bauindustrie (Ed.), Optimierung der Wertschöpfungskette Bau (1st Edition). Berlin / Düsseldorf, 2005, pp. 25–36.

Anvuur, A. / Kumaraswamy, M. (2012). *Promises, pitfalls and shortfalls of guaranteed maximum price (GMP) approach: A comparative case study* (13 December 2012).

Bartosch-Schmitz, H. / Blank, A. / Hahn, H. / Meyer, H. / Kazmierczak, J. (2005). *Handelsbetriebslehre* (5th Edition). Troisdorf: Bildungsverlag EINS-Gehlen, 2005.

Berner, F. / Kochendörfer, B. / Schach, R. (2013). *Grundlagen der Baubetriebslehre 2: Baubetriebsplanung* (2nd Edition). Wiesbaden: Springer Vieweg.

Berner, F. / Kochendörfer, B. / Schach, R. (2015). *Grundlagen der Baubetriebslehre 3: Baubetriebsführung* (2nd Edition). Wiesbaden: Springer Vieweg.

Birtel, T. (2002). *EU-Osterweiterung – Betriebliche Strategien zur Erschließung der Baumärkte in den Beitrittsstaaten*. In: Zentralverband des Deutschen Baugewerbes / Betriebswirtschaftliches Institut der Bauindustrie: EU-Osterweiterung – Chancen und Risiken für Bauunternehmen. Berlin / Düsseldorf 2002, Vol. 50, pp. 73–82.

Bundesministerium für Verkehr, Bau und Stadtentwicklung (BMVI) (2012). *Handbuch für die Vergabe und Ausführung von Bauleistungen im Straßen- und Brückenbau (HVA B-StB 2012)*. Available at http: / / www.bmvi.de / DE / Home / home_node.html (accessed 1 Oct. 2015).

BWI-Bau (Ed.) (2013). *Ökonomie des Baumarktes - Grundlagen und Handlungsoptionen: Zwischen Leistungsversprecher und Produktanbieter.* Wiesbaden: Springer Vieweg.

Coenenberg, A. G. / Fischer, T. M. / Günther, T. (2012). *Kostenrechnung und Kostenanalyse* (8th revised Edition). Stuttgart: Schäffer-Poeschel.

Deuschle, F.-M. / Meffle, G. / Gönner, K. (1993). *Wirtschaftsrechnen – Rechenwerk für Kaufleute* (31st Edition). Bad Homburg vor der Höhe: Gehlen, 1993.

Drees, G. / Paul, W. (2015). *Kalkulation von Baupreisen: Hochbau, Tiefbau, schlüsselfertiges Bauen; mit kompletten Berechnungsbeispielen* (12th updated and expanded Edition). Berlin: Beuth.

Drukarczyk, J. (1998). *Kapitalkosten*. In: Busse von Colbe, W. / Pellens, B., Lexikon des Rechnungswesens – Handbuch der Bilanzierung und Prüfung, der Erlös-, Finanz-, Investitions- und Kostenrechnung (4th Edition). München / Wien: Oldenbourg 1998, pp. 404–407.

Eisele W. / Knobloch, A. P. (2011). *Technik des betrieblichen Rechnungswesens: Buchführung und Bilanzierung, Kosten- und Leistungsrechnung, Sonderbilanzen* (8th revised and expanded Edition). München: Vahlen.

Euler Hermes Aktiengesellschaft (2016). Länderliste - Informationen zu den Deckungsvoraussetzungen. Available at http://www.agaportal.de/pages/dia/deckungspraxis/laenderliste.html. (accessed 8 Sep. 2016).

Fink, A. / Klein, W. (2008). *Der Bauvertrag nach BGB*. In: Jacob, D. / Ring, G. / Wolf, R. Freiberger Handbuch zum Baurecht (3rd Edition). Köln: Bundesanzeiger Verlag / Stuttgart: Fraunhofer IRB-Verlag 2008 § 2, pp. 65–167.

Floss, R. (2009). *Kommentar und Leitlinien mit Kompendium Erd- und Felsbau* (4th Edition). Handbuch ZTVE-Stb, Kirschbaum 2009.

German Federal Ministry of Economic Affairs and Energy: *Foreign Trade and Investment Promotion Scheme*, Web. 15 Feb. 2016 http: / / www.agaportal.de / en / index.html.

Girmscheid, G. (2008). *Baubetrieb und Bauverfahren im Tunnelbau* (2nd Edition). Berlin: Ernst & Sohn, 2008.

Gladen, W. (2014). *Performance measurement: Controlling mit Kennzahlen* (6th revised Edition). Wiesbaden: Springer Gabler.

Götze, U. (2010). *Kostenrechnung und Kostenmanagement* (5th Edition). Berlin: Springer.

Hamm, V. (1997). *Informationstechnikbasierte Referenzprozesse – Prozeßorientierte Gestaltung des industriellen Einkaufs*. Wiesbaden: Gabler, 1997.

Hauptverband der Deutschen Bauindustrie / Zentralverband des Deutschen Baugewerbes (Ed.) (1982). *Kosten- und Leistungsrechnung der Bauunternehmen – KLR Bau* (1st Edition). Wiesbaden / Berlin: Bauverlag / Köln: R. Müller / Düsseldorf: Werner, 1982.

Hauptverband der Deutschen Bauindustrie / Zentralverband des Deutschen Baugewerbes (Ed.) (2001). *Kosten- und Leistungsrechnung der Bauunternehmen – KLR Bau* (7th Edition). Wiesbaden / Berlin: Bauverlag / Düsseldorf: Werner, 2001.

Hauptverband der Deutschen Bauindustrie e. V. (Ed.) (2007). *BGL 2007 Baugeräteliste.* Bauverlag BV GmbH, Gütersloh 2007.

Hochtief AG (2000). *Geschäftsbericht 1999*, Essen 2000.

Hochtief AG (2001). *Geschäftsbericht 2000*, Essen 2001.

Jacob, D. (1997). *ALDI am Bau – Gedanken zu einer Analogie zwischen Handel und modernem Baugeschehen*. In: Verband der Bauindustrie für Niedersachsen (Ed.), Festschrift für Egon Heinrich Schlenke, Hannover 1997, pp. 505–509.

Jacob, D. (Ed.) (2009). *Endbericht für das Forschungsvorhaben: "Entwicklung von Musterverträgen für eine innovative Form der Arbeitsgemeinschaften zwischen mittelständischen Bauunternehmen und Planungsbeteiligten"*, Available at http: / / tu-freiberg.de / sites / default / files / media / baubetriebslehre-3408 / Projekte / ArgePlanungundBau / endbericht_arge_mustervertrag.pdf (accessed 11 Mar. 2016).

Jacob, D. (1998). *Referenzprozesse für optimale Beschaffungsstrategien.* In: Baumarkt, Issue 97 / 1998, Vol. 9, pp. 40–45.

Jacob, D. (2000a). *Strategie und Controlling in der mittelständischen Bauwirtschaft.* In: Baumarkt, Issue 99/2000, Vol. 3, pp. 52–56.

Jacob, D. (2000b). *Managementstrategien eines Projektentwicklers bei kontaminierten Grundstücksflächen*. In: TerraTech, Issue 9/2000, Vol. 2, p. 53 f.

Jacob, D. (2001). *Effizienzgewinne bei privatwirtschaftlicher Realisierung öffentlicher Hochbauten: Britische Erfahrungen auf dem wissenschaftlichen Prüfstand.* In: Bauindustrie aktuell 2001, Vol. 5–6, p. 10 f.

Jacob, D./Mollenhauer, A. (2002). *EU-Osterweiterung – Betriebliche Strategien zur Marktbehauptung im Inland*. In: Zentralverband des Deutschen Baugewerbes/Betriebswirtschaftliches Institut der Bauindustrie: EU-Osterweiterung – Chancen und Risiken für Bauunternehmen, Berlin 2002, Vol. 50, pp. 52–72.

Jacob, D./Leinz, J. (2005). *Schlüsselfertiges Bauen – Beschaffung von Nachunternehmerleistungen.* In: Beschaffungsmanagement - Revue de l'acheteur 2005, Vol.1, pp. 5–7.

Jacob, D./Heinzelmann, S./Stuhr, C. (2008). *Rechnungslegung und Bilanzierung von Bauunternehmen und baunahen Dienstleistern.* In: Jacob, D./Ring, G./Wolf, R. (Ed.), Freiberger Handbuch zum Baurecht (3rd Edition). Köln: Bundesanzeiger. Stuttgart: Fraunhofer IRB-Verlag, 2008, § 24, pp. 1383–1422.

Jacob, D./Winter, C./Stuhr, C. (2008). *Baukalkulation.* In: Jacob, D./Ring, G./Wolf, R. (Ed.), Freiberger Handbuch zum Baurecht (3rd Edition). Köln: Bundesanzeiger Verlag/Stuttgart: Fraunhofer IRB-Verlag, 2008, § 21, pp. 1099–1194.

Keidel, C. (2009). *Entwicklung und Gestaltung eines Unternehmenscontrolling in mittelständischen Bauunternehmen – Unter Berücksichtigung von zwei empirischen Untersuchungen im zeitlichen Vergleich* (2009 Edition). Wiesbaden: Gabler.

Klee, L. (2015). International Construcion Contract Law. Chichester: John Wiley & Sons.

Leinz, J. (2001). *Grundzüge einer strategischen Beschaffung in der Bauindustrie.* In: Beschaffungsmanagement - Revue de l'acheteur 2001, Vol. 1, pp. 10–12.

Lingenfelser, H. (2001). *Senkkästen*. In: Smoltczyk, U. (Ed.), Grundbau-Taschenbuch, Part 3: Gründungen (6th Edition). Berlin: Ernst & Sohn 2001, pp. 233 ff.

Perridon, L./Steiner, M./Rathgeber, A. W. (2009). *Finanzwirtschaft der Unternehmung* (15th Edition). München: Vahlen, 2009.

Porter, M. E. (1999). *Wettbewerbsstrategie – Methoden zur Analyse von Branchen und Konkurrenten* (10th Edition). Frankfurt am Main/New York: Campus-Verlag, 1999.

Schmieg, A. (2005). *Ausweitung der Wertschöpfung in einem mittelständischen Unternehmen.* In: Zentralverband des Deutschen Baugewerbes/Betriebswirtschaftliches Institut der Bauindustrie (Ed.), Optimierung der Wertschöpfungskette Bau. Berlin/Düsseldorf 2005, pp. 37–48.

Speer, U. (1997). *Bauaufträge mit Gewinn – Strategien zur Kalkulation und Preisermittlung für den Bauunternehmer*. Köln: R. Müller, 1997.

Stuhr, C. (2007). *Kreditprüfung bei Bauunternehmen* (1st Edition). Wiesbaden: Deutscher Universitäts-Verlag, 2007.

Stuhr, C. (2009). *Balanced Scorecard*. In: ibr (Informationen Bau-Rationalisierung). Magazin der RG-Bau im RKW, Issue 39/2009, Vol. 4, pp. 14–16.

Süchting, J. (1998). *Weigthed Average Cost of Capital*. In: Busse von Colbe, W./Pellens, B.(Ed.), Lexikon des Rechnungswesens – Handbuch der Bilanzierung und Prüfung, der Erlös-, Finanz-, Investitions- und Kostenrechnung, (4th Edition). München/Wien: Oldenbourg 1998, p. 745.

The American Institute of Architects (2003). *The Architect's Guide to Design-Build Services.* New Jersey: John Wiley & Sons, 2003.

VOB (C) (2009). *Vergabe- und Vertragsordnung für Bauleistungen (C).* DIN -Deutsches Institut für Normung e.V. (Ed.) (2009 Edition).

Wagner, B./Klinke, D. A. (2000). *Aus der Bilanz abgeleitete Finanzplantechnik im Stahlbau.* In: Jacob, D. (Ed.), Aktuelle baubetriebliche Themen, Summer 1999, Freiberger Arbeitspapiere Nr. 2, Freiberg 2000, pp. 35–62.

Weissmann, A./Schwarz, S. (1997). *Anleitung zur praktischen Strategieentwicklung*. In: Schwarz, S./Weissman, A./Schmutzer, M. O. (Ed.), Zukunftssicherung für die Bauwirtschaft – In vier Schritten aus der Krise (1997 Edition). Wiesbaden: Gabler, pp. 55–125.

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