PROCESS MANAGEMENT
– LEAN CONSTRUCTION

Christoph Motzko
Włodzimierz Martinek
Jörg Klingenger
Florian Binder

Darmstadt, Warsaw, 2011

"This project has been funded with support from the European Commission under the Lifelong Learning Programme. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein."
These manuals were developed within the scope of the LdV program, project number: 2009-1-PL1-LEO05-05016 entitled “Common Learning Outcomes for European Managers in Construction” ("Model of certification and mutual recognition of qualifications of construction managers and engineers - development of manuals for post-graduate and supplementary studies"), Stage II. The project was promoted by the Department of Construction Engineering and Management, Faculty of Civil Engineering at the Warsaw University of Technology. Partners of the project were:

- Technische Universität Darmstadt (Germany)
- Universidade do Minho (Portugal)
- Chartered Institute of Building (Great Britain)
- Association of European Building Surveyors and Construction Experts (Belgium)
- Polish British Construction Partnership (Poland)

Within this part of the project the following manuals were developed:

M8: Risk Management (130)
M9: Process Management – Lean Construction (90)
M10: Computer Methods in Construction (80)
M11: PPP Projects in Construction (80)
M12: Value Management in Construction (130)
M13: Construction Projects – Good Practice (80)

The scope of knowledge presented in the manuals is necessary in activities of managers - construction engineers, managing undertakings in conditions of modern market economy. The manuals are approved by the European AEEBC association as a basis for recognizing manager qualifications. Modern knowledge in the field of management in construction, presented in the manuals, is one of prerequisites to obtain EurBE (European Building Expert) cards, a professional certificate documenting the qualification level of a construction manager in EU.

The manuals are designated for managers - construction engineers, students completing postgraduate studies “Management in construction” and students completing construction studies. Postgraduate studies are a recognized program, and graduates receive certificates recognized by 17 national organizations, members of AEEBC.

The manuals were translated by Lingua Nova translation office.

More information:

www.leonardo.il.pw.edu.pl
www.psmb.pl
www.aeebc.org
# TABLE OF CONTENTS

## CHAPTER 1
**INTRODUCTION - LEARNING OUTCOMES** ......................................................... 5  
(C. MOTZKO)

## CHAPTER 2
**DEFINITION OF A PROCESS AND MANAGEMENT OF PROCESSES IN CONSTRUCTION** ................................................................. 10  
(C. MOTZKO)

1. **JUSTIFICATION OF PROCESS -BASED APPROACH IN
   CONSTRUCTION** .................................................................................................. 10
   1.1 Organisational structure ................................................................. 14
   1.2 Organisation of performance of construction works ...................... 17
   1.3 A process-based approach ............................................................ 19

2. **DEFINITION OF THE TERMS “PROCESS” AND “PROCESS
   MANAGEMENT”** .......................................................................................... 20

3. **PROCESS MODELLING METHODOLOGY** .................................................. 23

## CHAPTER 3
**THE MODEL OF PROCESSES IN A CONSTRUCTION ENTERPRISE** .... 31  
(C. MOTZKO)

1. **INTRODUCTION TO THE MODEL OF PROCESSES IN A
   CONSTRUCTION ENTERPRISE** ................................................................. 31

2. **MANAGEMENT PROCESSES IN A CONSTRUCTION
   ENTERPRISE** ............................................................................................. 35

3. **OPERATIONAL PROCESSES IN A CONSTRUCTION
   ENTERPRISE** ............................................................................................. 35
   3.1 Basic processes .................................................................................. 36
   3.2 Auxiliary processes ........................................................................... 42

## CHAPTER 4
**SELECTED OPERATIONAL PROCESSES IN A CONSTRUCTION
   ENTERPRISE** ................................................................................................. 67  
(C. MOTZKO, W. MARTINEK, J. KLINGENBERGER)

1. **BASIS OF OPERATIONAL CONTROL OF PROCESSES** .................... 67
   1.1 Basis for comparison of the actual and planned condition .............. 67
   1.2 Basic controlling of construction costs ............................................ 70
   1.3 Basic controlling of the schedule of works ..................................... 73

2. **PREPARATION OF WORK PROCESSES** ............................................. 76
   2.1 Classification of work processes ....................................................... 76
   2.2 Basic components of construction processes and their conditions 79
4.2.3 Procedures of preparation for implementation of construction processes ................................................................. 83

4.3 PREPARATION OF THE CONSTRUCTION SITE................................. 91
  4.3.1 General conditions .................................................................. 91
  4.3.2 The principles of designing of the basic site development components ................................................................. 95

4.4 OCCUPATIONAL HEALTH AND SAFETY....................................... 109
  4.4.1 Introduction.......................................................................... 109
  4.4.2 Selected components of the construction documentation pertaining to OHS ............................................................. 113
  4.4.3 Occupational risk assessment methodology for boarding works 114

4.5 QUALITY MANAGEMENT.......................................................... 120
  4.5.1 Quality of processes, products and systems in construction ...... 120
  4.5.2 Rules and conditions of quality management improvement ...... 122
  4.5.3 Control of contract documents ............................................. 123
  4.5.4 Control of design processes ................................................. 125
  4.5.5 Conducting construction meetings ........................................ 127
  4.5.6 Recruitment of subcontractors ............................................. 128
  4.5.7 Control of works performed earlier by other (sub) contractors .. 129
  4.5.8 Claims related to defects....................................................... 130

CHAPTER 5
LEAN CONSTRUCTION – INTRODUCTION............................................. 132
(C. MOTZKO, F. BINDER)
  5.1 LEAN THINKING AND LEAN MANAGEMENT............................. 132
  5.2 LEAN CONSTRUCTION........................................................... 137
  5.3 LEAN CONSTRUCTION: EXAMPLES OF APPLICATION .......... 145

BIBLIOGRAPHY .............................................................................. 152
CHAPTER 1

INTRODUCTION - LEARNING OUTCOMES
(C. MOTZKO)

Construction of buildings is usually a serious undertaking from the technical, economic and organisational point of view. It is aimed at transformation of the idea or concept of the investor, architect or designer into a real facility through a complex structure of processes while maintaining the defined technical, legal, functional, aesthetic, socio-economic, environmental and other individual restrictions. Construction consists of production of individual facilities within the framework of socio-technical systems, consisting of a number of entities, such as the principals, architects, designers, construction companies, administrative bodies or suppliers of equipment. At present, the most significant challenges faced by the construction sector include also the environmental dimension and the dimension of sustainability. The construction sector is characterised by the highest potential for limiting the emission of CO$_2$. For a long time, the environmental dimension of construction, along with numerous social and economic conditions of implementation and operation of a structure, has required design based on familiarity with the life cycle of the construction facility. Closing the material circuit (closed substance cycle and waste management), environment-friendly production of construction materials and the proper construction materials on the construction site, as well as devising a strategy for real estate management are just selected examples to illustrate this trend. Environmental certificates for buildings, based on such systems as LEED, BREEAM or Deutsches Gütesiegel Nachhaltiges Bauen, have been gaining importance. Figure 1.1 presents various stages of the building life cycle, divided into phases of the project, the facility and its regeneration.

---

1 IPC (2007)
The project phase is a segment in the life cycle, in which the construction facility idea or concept is implemented through development and investment decisions, and then through design and construction. The facility phase describes day-to-day operation of the building. The design phase returns in the life cycle of the structure, when the mode of its operation changes substantially, or its existing condition changes to the extent, which makes it necessary to conduct design works, associated with the requirement to obtain an approval of the administrative bodies.

A construction undertaking, as a complex task, which is largely based on division of work, encompasses various design, advisory and construction tasks, which are implemented at various stages (complex of operations\(^3\)). Therefore, complex organisational structures are usually established; within the framework of these, legal and natural persons cooperate on the basis of specific contractual conditions. Construction undertakings are usually limited by a time frame and characterised by unique conditions. Therefore, implementation of a construction undertaking is a substantial challenge for all of the entities involved. It should be kept in mind that each of these entities is aiming to achieve the objectives of its companies and organisations which, on the other hand, take into account the needs of various stakeholders, such as clients, society, shareholders of a company or employees.

\(^2\) Hertle/Motzko (2007)  
\(^3\) Jaworski (1999)
This is all the more important as at present, in the European Union countries, there is strong competition in the construction sector which forces construction companies to rationalise permanently their structures and processes. It should also be noted that the success of a company or an organisation depends on the qualifications and experience of its employees, their independence and creativity in the context of the defined competence.

A dominant term with regard to organisation, controlling and management of a company is now the PROCESS. A process-based approach to management serves as a new basis for formulation of tasks, structures and modes of operation of companies. The same applies to construction. A process-based approach is reasonable, since in the future, along with progressing specialisation of functional areas of companies, such as manufacturing, accounting, procurement or logistics, the scope of their mutual coordination will be growing. This coordination has been generating expenditures, which are partially associated with substantial costs. Development and application of new IT systems has not been able to balance this deficit fully. Thus, in organisation science, the traditional function–based approach, dominated by the distinction by organisation of the company structure (organisational structure, division of work, division of tasks, competences and scopes of responsibility) and organisation of the course of works (the time and space aspect, objective-oriented structuring of work processes) has been extended. The function-based approach to enterprises has been complemented by a process-based approach. As early as 1934, Nordsieck⁴ pointed to the necessity to apply such approach⁵. In the late eighties of the previous century, process-oriented management of enterprises became a standard, and its reasonability was claimed by such authors as Gaitanides⁶, Porter⁷, Davenport⁸ or Hammer and Champy⁹. Modification of standards, including ISO 9000/ISO 9001, was also a logical continuation of the new approach. Thus, the examined process-based approach to functioning of an enterprise or organisation of a construction undertaking somewhat complements the multidimensional approach, which today is a necessity. On the other hand, the organisational structure remains one of the basic elements of shaping of an enterprise.

---

⁴ Nordsieck (1934)
⁵ Becker, Kugeler, Rosemann (2008)
⁶ Gaitanides (1983)
⁷ Porter (1989)
⁸ Davenport (1993)
⁹ Hammer/Champy 1993
Apart from the focus on processes, it is also necessary to mention the fact that companies in the construction sector are also client-oriented. This is a significant aspect, as there is a difference between consumers of mass-produced serial products and a client in the property sector, operating on the basis of an individual construction contract. Within the framework of this manual, however, this issue can be discussed only to a limited extent.

This textbook M9 “Management of construction processes and lean construction” presents the basic knowledge on processes and structures of processes in the organisation of construction undertakings and in a construction enterprise. Particular emphasis was put on the construction phase, at the same time discussing selected components of the preconstruction phase. The basis for clarification of processes and correlations between them is the process structure model for a construction enterprise, presented in figure 1.2. The structure of processes presented can be used only as an exemplary diagram (model), since in a real construction enterprise, processes and correlations between them are defined on the basis of a specific profile of construction services and conditions of the market, which is the area of operation of a given company.

![Figure 1.2. An example of the structure of processes in a construction enterprise](image)

10 As in: Girmscheid/Motzko (2007) and Schmelzer/Sesselmann (2010)
Basic information on processes and process management is presented in Chapter 2 of this manual. It discusses the methodology of process modelling, used in construction. Basic definitions of individual processes of the structure presented in Figure 1.2 are provided in Chapter 3. Chapter 4 describes selected operating processes (defined also as business processes) in detail. This knowledge, as well as basic information on lean management, is necessary to develop the manufacturing philosophy behind lean construction, presented in Chapter 5. Both theoretical information and practical examples are presented for this purpose.

Students, who have read and analysed this textbook, should attain the following learning outcomes:

- General understanding of the terms “process” and “process modelling” in construction. Ability to model process and to devise monitoring of processes.
- General understanding of the structure of processes in a construction company and in organisation of construction undertakings with emphasis on the construction phase. Basic ability to create organisation of construction undertakings and hierarchical process structures.
- General understanding of the concept of lean construction on the basis of a practical example.
CHAPTER 2

DEFINITION OF A PROCESS AND MANAGEMENT OF PROCESSES IN CONSTRUCTION (C. MOTZKO)

2.1 JUSTIFICATION OF PROCESS-BASED APPROACH IN CONSTRUCTION

In relation to other branches of industry, construction has some specific features, which must be taken into account in the context of shaping of organisation of enterprises and formulation of tasks with regard to defining of individual processes in the structures of management and operation processes (see Figure 2.1). These include:

- **Specific conditions of the construction market.** Demand and supply in construction are usually focused on the tender stage. Within the framework of tenders, construction companies attempt to get contracts for implementation of a construction undertaking.

- **Availability-oriented industry.** The sector generally operates on the basis of construction of individual facilities (products) on the basis of individual orders (construction contracts), and thus it must maintain the appropriate production capacity, not knowing precisely, when it will be used. The time, place and scope of performance of construction services are specified by the ordering party.

- **Completion of individual orders.** The client defines engagement of resources to some extent, because, as the result of individual design of the facility and specification of limited time for implementation of the
construction project, appropriate building materials, production technologies and capacities (labour force and machines). Standardisation of work flows is possible only to a limited extent due to the constantly changing conditions.

- **Multiple organisational correlations (external and internal relations).** Implementation of construction undertakings is associated with very intensive division of work at the stage of preparation of the design documentation, planning and implementation of construction works and operation of the facility. All this enforces creation of complex organisational forms, which are established for a specific time period.

- **Contract amendments.** During implementation of a construction undertaking, the client may change the scope of construction services at any stage of design and implementation of the investment period. The so-called “frozen zone”, which is encountered in other sectors of industry, performed on regular basis, in which changes of the scope of works are not allowed, usually does not exist in construction.

- **Strongly regulated public construction area and sectoral investments.** In the European Union, there are established procedures for tenders and awarding of public and sectoral contracts, which must be followed.

- **Dependency of production processes on weather conditions.** Production in the construction trade depends greatly on weather conditions. Low air temperatures and intense rainfall or snowfall may lead to discontinuation of works due to technological reasons. In this aspect, there is a visible difference between the construction sector and those sectors of industry in which works are performed on fixed, regular basis (manufacturing plants and factories).

- **Ergonomics.** Building production, despite the high level of mechanisation, is still dependent upon tasks performed manually. In fact, the speed of processes depends on human beings.

- **Dependency on the infrastructure.** Production in the construction trade depends greatly on flexible availability of various components of the infrastructure, such as streets, supply and discharge systems (water, sewage, energy), telecommunication and other systems. Availability of these is hindered as the facilities under construction are dispersed and their dimensions are substantial.

- **Life cycle and sustainability of building facilities.** In Chapter 1, we mentioned the high potential of construction to reduce the emission of CO₂. In the context of requirements for building facilities in the process of design and overall assessment after completion, it is necessary to mention the increasingly significant certification systems, such as LEED (USA),
BREEAM (GBR), Green Star (AUS), HK BEAM (Hong Kong), Deutsches Gütesiegel Nachhaltiges Bauen (D), CASBEE (Japan) and HQE Haute Qualité Environnementale (F). Worth noting are the criteria of sustainable development, referring to the construction site and construction processes within the framework of the Deutsches Gütesiegel Nachhaltiges Bauen certification system – fragments are quoted below:

Quotation:

"Criterion 48: Construction site/ construction process.

Objective: it is necessary to minimise the environmental impact, and at the same time, protect the health of all participants. Assessment of the construction site/ process includes the following criteria:

1. Construction site with waste minimisation: During construction, reconstruction or demolishing of a structure, rubble, soil, remnants of materials, packaging, wood etc. is collected. Such waste should be either avoided or processed. Waste which can neither be avoided nor processed should be removed in an environmentally-friendly manner.

2. Construction site with low noise level: constant impact of noise may lead to irritation of the nervous system, and thus cause health impairment. In densely populated areas, construction noise is the second most significant source of noise after transport noise. Therefore, it is necessary to prove that construction noise does not exceed the total sound volume or is limited using the appropriate means.

3. Low dust level construction site: dust usually emerges as a result of processing of construction materials within the framework of various activities. Avoidance of dust is a very significant contribution to protection of the environment and the people. Additionally, the environment should be protected against damages resulting from use of specific materials.

4. Environmental protection on the construction site: at the construction stage, it is necessary to protect the soil and groundwater against discharge of harmful materials and other unacceptable activities. Chemical impact can be caused by products and the course of works, which results in discharge
of gases, liquids and solids into the soil. Further impact, such as excessive soil compacting, should be avoided.”

End of quotation

Another important aspect is the high level of complexity of design processes in construction. Usually, there is a division between designing of a facility and implementation of construction, which is associated with the hierarchisation of activities between the ordering parties (investor), the architect/designer and the entity implementing the task (see figure 2.1). Two examples are provided below:

- The investor decides on whether the specific scope of documentation, obtained from the architects/designers will be processed further. A basis for decision on continuation or modification of design works is the assessment of the degree of compliance with the requirements and limitations, specified by the investor (the set of objectives of the construction undertaking). The criteria may include the estimated investment expenditures, maintenance of the quality level, implementation of the corporate identity and other factors.
- The construction process may be commenced only after the appropriate detailed documentation is prepared and approved by the investor, as well as the appropriate administrative bodies.

Ability to control the complexity of the project refers to shaping of the structure and processes both within the construction enterprise and in organisation of construction undertakings, which are usually implemented for a specific period of time. Usually, there is a division into organisation of structure (organisational structure) and organisation of flows (space and time aspect), as well as shaping of the form of organisation – functional or according to facility.

---

11 BMVBS Deutsches Gütesiegel Nachhaltiges Bauen
2.1.1 ORGANISATIONAL STRUCTURE

The organisational structure defines the static system of organisational units and regulates the scope of responsibility for implementation of corporate tasks according to the division of work. The division of tasks is associated with the objectives of the enterprise. Organisation of the structure divides the enterprise or organisation into organisational units, regulating the structure, competences and

---

12 Koch, 2010.

13 Gabler
responsibility of persons (positions) functioning in the organisation. Creation of the organisational structure is possible thanks to various methods. One of these (see figure 2.2) is based on defining the objective of a service during the first stage, within the framework of the so-called analysis of tasks, dividing it in accordance with specific criteria into partial tasks that can be transferred to participants, or, according to the further space of division, into basic tasks. The following components can serve as the criteria: performance (e.g. procurement, assembly, and production), facility (general or engineering construction), rank (e.g. the competence of management, tender, order, construction implementation, and warranty phase) or relations to the result of activity (e.g. basic or auxiliary task). During the next stage, within the framework of synthesis of tasks, basic tasks are entered into the activity areas. Work positions are defined on the basis of these. The criteria include contractors for individual tasks, inventories, space and time. Individual positions are combined into superior management levels. The superior ones are associated with the competence of issuing orders. Work positions should be manned with properly qualified employees who should have the appropriate authorisations to perform specific tasks. Assignment of tasks and competences means the necessity of approaching the duties entrusted, referred to as the scope of responsibility, in a professional manner.

Figure 2.2. Analysis and synthesis of tasks (Own figure on the basis of 15)

---

14 Gabler
15 Gabler
Functional structure of the organisation. As for the functional structure of the organisation, the division takes place in accordance with the uniform organisational units, such as procurement, production, administration or accounting. This is a top-down process. There are complex correlations between the functional areas and difficulties in reaching consensus, which enforces a high level of coordination expenditures. This may lead, among other things, to centralisation of decisions.\textsuperscript{16} There is also a threat that the functional areas might become focused only on their individual tasks, thus becoming unable to see the broad perspective of the undertaking.

Divisional structure of the organisation. As for divisional forms of organisation (branches), the division of rights and responsibilities is based on the rule of grouping of objects (e.g. groups of products, clients or regions) and is based on isolation of internal segments of the organisation. A typical component is visible separation cost centers and profit and contribution centers. Coordination of basic functions takes place not in the central areas, but within the branches\textsuperscript{17}. In comparison with functional structures of the organisation, divisional forms may generate higher production costs which are caused, for example, by the need for higher levels of procurement and the limited possibility of disposing of these (limited exchange between units).

Functional and divisional structures are one-line structures, considered to be model structures.

Matrix organisation. In construction, since the 1980s, the discrepancy between the functional and divisional structure is overcome, among other things, by applying matrix organisation. In this structure, construction projects are integrated as equal organisational units in the organisational system of the enterprise. Employees of a matrix organisation may be subject to double subordination, on one hand to the management of the corporate unit, on the other to the management of a given construction undertaking. This may lead to conflicts due to the fact that employees receive competing orders from two different supervision units. Figure 2.3 presents an example matrix organisation for construction of Okęcie Airport. The general project manager was superior to managers of individual construction sections, responsible for construction of the passenger terminal, the kitchen (catering) and the cargo terminal. Each construction section manager cooperated with the architect and was supported by a foreman. Individual managers for specialised

\textsuperscript{16} Laux/Liermann (2005)
\textsuperscript{17} ibidem
works, such as construction, facade, floors, painting works etc., which functioned both at the headquarters of the company and on the construction site, were at the same time subordinate to the general management at the headquarters and the construction section managers (passenger terminal, catering and cargo terminal). An advantage of this method is the possibility of conducting interdisciplinary works, flexibility, innovation and creative forms of coordination. Matrix organisations generate relatively high management costs.

![Figure 2.3. An example of matrix organisation of a construction project](image)

**2.1.2 ORGANISATION OF PERFORMANCE OF CONSTRUCTION WORKS**

Organisation of performance of construction works reflects the time and space aspects of implementation of works. It regulates and controls such aspects as the order (when?), conditions (where?), responsibility (who?) and result (objective?) of the activity (what?). The organisational components (contractors, tasks, material means etc.) are to be shaped in relation to time and space flows so that individual

\[\text{Specialisations} \quad \text{Passenger terminal} \quad \text{Kitchen} \quad \text{Cargo terminal}\]

<table>
<thead>
<tr>
<th>General construction management</th>
<th>Construction manager</th>
<th>Construction manager</th>
<th>Construction manager</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chief foreman</td>
<td>Foreman</td>
<td>Foreman</td>
<td>Foreman</td>
</tr>
<tr>
<td>Specialised manager</td>
<td>structures</td>
<td>floor</td>
<td>facade</td>
</tr>
<tr>
<td></td>
<td>equipment</td>
<td>other</td>
<td></td>
</tr>
</tbody>
</table>

\[Bürklin/Motzko 1993\]
stages of work are fitted to one another precisely.\textsuperscript{19} A well thought-out schedule of works is decisive for proper implementation of construction works. According to REFA, organisation of construction works includes “design, shaping and control of work systems in order to attain an economic and ergonomic (humanitarian) result of activity.”\textsuperscript{20} In the discussed context, it is possible to distinguish planning (design) of objectives and design of tasks (see figure 2.4).

Figure 2.4. Structure of design (complemented in accordance with\textsuperscript{21})

The term “control” refers to ordering, supervision and ensuring implementation of tasks with regard to quantity, quality, deadlines and costs\textsuperscript{22}. The issue of complexity of control of processes in construction projects will be discussed in chapter 4.1.

\footnotesize
\begin{flushleft}
\textsuperscript{19} Gabler
\textsuperscript{20} REFA (1984)
\textsuperscript{21} ibidem
\textsuperscript{22} ibidem
\end{flushleft}
2.1.3 A PROCESS-BASED APPROACH

One of the new management methods is process-based management, mentioned already in Chapter 1 (Gaitanides\textsuperscript{23}, Porter\textsuperscript{24}, Davenport\textsuperscript{25} or Hammer and Champy\textsuperscript{26}). It assumes separation from the functional or divisional organisational structure. The enterprise is aimed at defining and organizing processes, putting emphasis on the so-called operational processes (defined also as business processes). Operations aimed at optimisation take into account not functions, but processes. In organisation of processes, partial tasks are not due to the general task of the enterprise in the top-down structure (like in the functional and divisional organisation), but they are subject to a bottom-up approach\textsuperscript{27}. The functional or divisional rule in relation to division of work (differentiation) and coordination (integration) is subjected to processes. Responsibility for the process is shifted to the process owner. Apart from increase in effectiveness and efficiency, emphasis in operation of the enterprise is put on client satisfaction. It is regarded as obvious that there is focus on the costs, quality and time, as well as the employees. In order to eliminate the boundaries between positions, branches and even companies, it is possible to apply the so-called team-based concepts.\textsuperscript{28}

For the purpose of reliable functioning of construction companies and organisation of construction undertakings, it is necessary to apply an integrated approach to various modes of functioning of the organisational structure and organisation of flow of works (processes) and adapt them to existing conditions. This means that the process-based approach cannot fully replace the methods of creating organisational structures on the functional or divisional basis and implementation of flow of works. Therefore, the organisation structures should always be shaped within the space between the (vertical) functions and (horizontal) processes.\textsuperscript{29}

\textsuperscript{23} Gaitanides (1983)
\textsuperscript{24} Porter (1989)
\textsuperscript{25} Davenport (1993)
\textsuperscript{26} Hammer/Champy (1993)
\textsuperscript{27} Sydow (2006)
\textsuperscript{28} Gabler
\textsuperscript{29} Seidlmeier (2002)
2.2 DEFINITION OF THE TERMS “PROCESS” AND “PROCESS MANAGEMENT”

**Process.** The course of construction works in an enterprise is a result of design guidelines and further modifications, resulting from product and technology innovations, corrections of existing systems or prevention to eliminate errors and defects. The course of works is reflected formally by the hierarchy of processes.

At first, it is necessary to define the term PROCESS.

Davenport\(^{30}\) defines the process in terms of execution, placing it in the space and time structure, thus:

„A PROCESS – a set of activities or actions aimed at achieving the expected result through transformation of the input condition into the output condition.”

A process as a transformational course of work is explained normatively.

EN ISO 9000:2005 defines “process” in clause 3.4.1 as a set of various correlated and mutually dependent operations (activities, actions), which transform the input (input data) into the output (output data, result). Every process is related to other processes through its inputs and outputs.

EN ISO 9001:2008 defines “process” as an operation (activity, action) or group of operations which uses resources or is conducted to allow for transformation of input data into output data (result).

Thus, a process is initiated in the defined input structure by an initiating event. Through individual activities, sets of activities or other transforming activities, the input structure is transformed to a specific output structure. In relation to construction, the term “process” can be defined as follows (Engelmann 2005)\(^{31}\).

---

\(^{30}\) Davenport (1993)
\(^{31}\) Engelmann (2005)
A process in construction is an integral, content-based/logical, time-defined set of operations (activities, actions) for the purpose of studying a given subject. Subject to it may be design services, works or construction services.

Processes can be classified according to various criteria. Classification of work processes is described in chapter 4.2.1.

In terms of organisation, two basic types of processes can be distinguished (see figure 1.2):

- **Management processes**: the task of processes belonging to this category is to formulate the objectives of the enterprise (definition of a mission), informing of these and supervision of their completion and strategic development of the enterprise;
- **Operational processes** (also known as business processes): aimed at achievement of objectives of functioning of the enterprise (production and construction and design services) and implementation of design guidelines, resulting from the sphere of management processes. Operational processes can be divided into basic and auxiliary processes. Basic processes specify the precise structure of construction production and services, usually as a logical set of works, resulting from work division (e.g. bidding, preparation of production, implementation of construction and services etc.). These generate income for the client. Auxiliary processes include services for management processes and for basic processes (such as accounting, controlling, occupational health and safety, risk management, management of human resources and quality etc.). These are necessary for the efficient functioning of the enterprise.

Process structures are systematised using the appropriate process hierarchies. Different planes of such hierarchy depend on the profile of operation of the enterprise. Chapter 2.3 presents an example of process modelling, allowing for generation of the appropriate process hierarchy in relation to a construction enterprise.

As for processes in organisation of construction undertakings, it is necessary to take into account the fact that the investor/ordering party exerts some impact, or even constitutional influence on the structure and implementation of processes. This impact is a function of individual contract conditions and legal principles of the contract. A simple example here can be timely obtaining of decisions of the investor for continuation, change or elimination of specific design results. Thus, within the framework of presentation of construction facility interior design patterns, for specific materials, it is necessary to take into account the long waiting
time for supply of materials. If the investor delays the decision on selection of these materials, this may lead to substantial consequences for assembly, disturbing the schedule of construction. Identification and quantification of individual components of such activities are thus significant for implementation of the project.

**Process management.** Process management is a set of all strategic, organisational, operational and technological means, aimed at shaping and improving the mode of functioning of the enterprise or administration, in the context of satisfaction of clients’ needs and achievement of own goals. Accordingly, process management should be created individually for a given organisational unit. Process management at a manufacturer of consumer goods is shaped in a different way than process management at a construction enterprise (characteristics of the construction industry – see chapter 2.1), although certain methods are applicable in both cases. The process-based approach means that the organisation uses a process or system of processes to achieve a specific result, which leads to constant control of processes and process structures. The main principles of process management include:

- Process management integrates (unifies) processes (management, basic and auxiliary processes) into a single system. Interests of organisational units should be adapted to the general objective;
- Process management takes into account overall organisation;
- Process management includes such fields of operation as focus on clients, focus on the process, focus on employees and focus on result;\(^\text{32}\)
- Process management permeates through the planes of hierarchy and of processes in the company;\(^\text{33}\)
- Process management may be profiled. For example, in the area of management of operational processes, emphasis is put on application of control of time and capacities, analysis of costs and constant improvement of technological processes and the course of auxiliary works.

The process-based approach provides enterprises, as sociotechnical systems, with the necessary flexibility, making it possible to respond to the so-called non-continuous (short term) changes in the dynamics of the surroundings (see chapter 3.3.2.1).

\(^\text{32}\) Binner (2010)
\(^\text{33}\) ibidem Darmstadt, 2010
2.3 PROCESS MODELLING METHODOLOGY

**Basics.** Application of the process-based management approach requires formal defining of processes, pertaining to organisation. This is achieved thanks to process models. A model is representative and it enables:\(^ {34}\):

- Understanding of the structure;
- Communication within the framework of the structure;
- Theoretical aids for organisation, assessment or critical analysis of the structure planned or its variants;
- Specification of requirements for the structure planned;
- Conducting experiments; which should not, cannot or may not be conducted for the original;
- Formulating/checking hypotheses on the observed or postulated phenomena.

Every model and every original modelled is described as a number of individuals and characteristics,\(^ {35}\) thus:

- An individual is an individually recognised, independent object which is visibly distinguishable from other individuals;
- The characteristics of the model are:
  - Features of individuals or other characteristics;
  - Relations between individuals or characteristics;
  - Activities related to individuals or characteristics.

Models of processes should allow for quick content-based comparison with real processes, including their complexity and correlations shown on the basis of a simple description which should be clear, understandable, flexible, adaptable and suitable for development\(^ {36}\).

Later in this manual we will present the process modelling method, which can be very well applied to production processes and to processes of rendering services at a construction company.\(^ {37}\)

---

\(^{34}\) Glinz (2005)

\(^{35}\) Glinz (2005)

\(^{36}\) Binner, 2010, s. 341

\(^{37}\) Motzko et al. (2010)
Production processes in construction can be perceived according to REFA methodology\textsuperscript{38}. This system has been recognised and used for decades. A basic element of REFA methodology is the description of work systems. Figure 2.5 below presents the basic work system structure according to REFA.

\begin{center}
\includegraphics[width=0.7\textwidth]{work_system_structure.pdf}
\end{center}

\textbf{Figure 2.5. Work system structure according to REFA}\textsuperscript{39}

According to REFA, work systems are described in term of work tasks, flow of works, input data, output data (result), human, operating means and environmental impacts. These terms have been defined as follows:

- Work tasks: objectives of the work system;
- Flow of construction works: spatial and time-based series of mutual influences of man and operational means;
- Input data: subjects of works, persons and information to be changed or used in accordance with the works assigned;

\begin{footnotesize}
\begin{enumerate}
\item REFA (1978a)
\item Ibidem
\end{enumerate}
\end{footnotesize}
• Output data (result): subjects of works, persons and information that has been changed or used in accordance with the works assigned;
• Man: work effort necessary to perform the works assigned;
• Operational means: capacities of means of production necessary to perform the works assigned;
• Environmental impacts: physical, organisational and social impact on the work system.

Work systems may emerge as simple or complex structures. A construction site or a construction enterprise constitute a macro-level work system, while a single workplace within the framework of this structure is a micro-level work system (see the example in figure 2.6).

The processes of design, building production and rendering of construction services may be presented as a description of the course of works with the applicable work systems in accordance with the process definition as an integral, content-based/logical and time-defined set of operations (activities, actions) for implementation of the project. In order to conduct various operations, associated with implementation of a construction undertaking, such as preparation of the cost estimate and a schedule of works, conducting of controlling and analyses of the course of works on the construction site, it is necessary to create a hierarchy of progress of construction works, allowing for division of processes into fragments or sections. A REFA – based model is presented in figure 2.7.
Figure 2.6. Construction site as a micro- and macro-work system\textsuperscript{40}

\textsuperscript{40} Landau/Wakula/ Rohmert (1996)
Figure 2.7 shows that in a complex work system, work processes of the micro- and macro-sphere divide individual activities into two fragments. The REFA system methodology will be discussed, using bridge construction as an example.

MICRO-SPHERE WORK PROCESSES have been divided into components from operation elements to operations:

- **OPERATION ELEMENTS** are the smallest elements of the work process that cannot be subdivided - neither in terms of description nor in terms of time measurement. They last about 0.001 to 0.01 min (0.06 – 0.6 s) and they are referred to as motion elements, which are basic movements executed by man, or procedure elements, which are basic operations executed by machines. Example: the carpenter reaches for a nail during the boarding works for the bridge abutment foundation.

- **OPERATION STEPS** are partial operation sections which integrate a closed set of operation components. They usually last for 0.01 to 0.1 min (0.6 to 6 s), although they may be longer. Example: placement of anchor in the bridge abutment foundation boarding.

---

41 Berg (1984)
• A SUB-OPERATION consists of several operation steps (integration of operation stages). Example: assembly of boarding of the bridge abutment foundation.

• AN OPERATION is a section of works, based on performance of a unit of the task ordered. The activity is repeated many times when executing the order. The operation usually consists of many partial activities, and sometimes of one or several operation stages, such as: bridge abutment foundation boarding, bridge abutment foundation reinforcement, or concreting of the bridge abutment foundation. An operation may be a component of a list of specification of works for the purpose of preparation of the construction schedule (analytical part of the schedule), or a cost estimate item.

MACRO LEVEL WORK PROCESSES are defined as follows:

• A PROCESS STEP consists of a sequence of operations (work flow components) that are necessary e.g. for the manufacture of a single part. For instance: construction of the bridge abutment foundations or construction of the bridge abutment walls. A process step may be a component of the work list specification for the needs of preparation of the construction schedule (the analytical part), as well as a cost estimate item.

• A SUB-PROCESS consists of several operation steps. Example: management of the construction site, construction of bridge abutments, construction of bridge pillars or construction of bridge spans.

• THE OVERALL PROCESS includes all operations and operation elements that are needed to perform the contract. In this example: construction of a working bridge.

General process concept for construction. The information presented above, concerning the processes and process modelling, allow for formulation of a general concept of a process in construction. This issue should remain as open and flexible as possible. Due to the fact that processes may appear in structures that are shaped both in accordance with the organisational structure and organisation of the course of works (for instance, in the hierarchy sub-processes, meta-processes or depending on the order of performance of processes as the antecedent process and the successor process), the process description must be reflexive. This allows for description of input-output correlations, which are typical for a process, at any level of detail. A standardised definition of a process is presented in figure 2.8.
The general process definition quoted allows for its application to any processes in construction. On this basis, the production process definition was developed. A process, which is naturally abstract, has been assigned specific components of the work system according to REFA, as described above. These components can be developed by adding some fixed or variable activities. The result of such modelling of a production process for construction is presented in figure 2.9.

Figure 2.9. A production process model for construction

Figure 2.10 presents an example structure of the process for reinforcement works which, within the framework of increasing of the level of detail provided, has been based on work flow sections of the micro-scale according to REFA.

---

42 Motzko et al. (2010)
43 ibid
Figure 2.10 confirms the flexibility of the definition quoted in the context of construction. Depending on the purpose of the operation, for instance, preparation of a specification of works for the purpose of cost estimation and preparation of a schedule of works, conducting controlling or analysis of work time (analysis of workplaces), it is possible to select the appropriate level of detail provided for the construction process structure.
CHAPTER 3

THE MODEL OF PROCESSES IN A CONSTRUCTION ENTERPRISE

(C. MOTZKO)

3.1 INTRODUCTION TO THE MODEL OF PROCESSES IN A CONSTRUCTION ENTERPRISE

The basis for functioning of construction enterprises is performance of construction works (possibly along with design services) and rendering of construction services. Within the framework of production processes, production factors are integrated in a manner that leads to emergence of material values or services, or a combination of both. Works or services performed are paid for by the ordering party. At a construction enterprise, two opposite flows emerge; of goods and financial resources (see figure 3.1). The flow of goods is contained in the area from procurement (e.g. raw materials, construction materials and services of subcontractors), through, production as the process consolidating the means of production, to the completed construction works (construction facilities) or services rendered. Flow of financial resources which includes such components as revenues from sale of construction works and services and ensuring financial resources.
The enterprise is obliged, according to legal provisions, to document properly the activities and events in its financial accounting. Information for assessment of activities, control and planning is received by the corporate management within the framework of managerial accounting. This manual shows only the basic differences between the two systems, that is:

- Financial accounting is regulated by the legal provisions in force, while managerial accounting is an individual system, created freely by the corporation;
- Recipients of financial accounting reports are external entities, while the managerial accounting reports are received internally;
- The scope of financial accounting reports includes the entire company, while the same does not have to be applicable to managerial accounting (e.g. it may encompass only the defined segments);
- Financial accounting reports are prepared periodically, while in managerial accounting they are adapted to the needs of the enterprise;
- In financial accounting, emphasis is put on the past, while in managerial accounting, depending on the needs of the company, it can be put on the past, the present or the future.

---

44 Girmscheid/Motzko (2007)
• Financial accounting information must be precise, as required by the legal provisions. The nature of managerial accounting information is operative.

Construction enterprises focus, in terms of their operation, on production processes and rendering of services, including acquisition and use of construction facilities. These processes are placed in between the objective and the result of action. This is illustrated by the structure of processes in figure 3.2.

**Figure 3.2: A model of process structure at a construction enterprise**

*The management processes* at a construction company are the primary plane for normative and strategic development of the entire organisation, thus providing a framework for operation (specification of the mission statement, parameters of development of the system and the organisation). In terms of operational management, basic conditions and rules of organisation of operational (business) processes are defined. Management processes, despite the medium- or long-term time horizon, are to be subjected to constant controlling.

*The operational (business) processes* reflects the forms of creation of value for the client. In literature, the economic dimension of the processes of creating quality is

---

45 As in Girmscheid/Motzko 2007 and Schmelzer/Sesselmann (2010)
often provided: “Creation of value as understood in economy is the difference between the production value generated and the previous contributions.”

Depending on the reference to the client, operational processes can be divided into basic and auxiliary processes. Basic processes constitute the direct benefit for the client and they are characterised by:

- Visible benefit for the client;
- Specific nature of the corporation/ uniqueness;
- Non-imitability;
- Non-replaceability.

 Auxiliary processes do not generate direct benefits for the client; however, they are necessary for implementation of basic processes.

Figure 3.2 presents an example structure of processes. Real construction enterprises model individual categories and structures of processes according to their business models. It is significant that construction companies engage in constant benchmarking in relation to the processes defined. In this context, benchmarking means a targeted process of identification of best practices of the strongest competitors or representatives of other sectors in order to constantly improve the processes, methods and organisational structures of own company. Chapters 3.2 and 3.3 contain basic information on the processes of management and operation. Detailed information on selected processes can be found in chapter 4. More information can be obtained from selected professional literature.

---

46 Gabler
47 Osterloh/Frost, J (2006)
48 Za: Binner (2010)
3.2 MANAGEMENT PROCESSES IN A CONSTRUCTION ENTERPRISE

Management processes perform the following functions:\textsuperscript{49}

\textit{Normative management.} Within the framework of normative management, a mission and vision of the enterprise is formulated and its objectives are defined. The normative management parameters constitute the core of development of the organisation and operational definition of processes. Restrictions for normative management are defined by the potential benefits for the stakeholders. These are the clients, employees, shareholders, suppliers and subcontractors, society and possibly related companies and other natural and legal persons, who have a specific interest in development of the company.

\textit{Strategic management.} Within the framework of strategic management, development of a strategy for achievement of the corporate mission and vision is implemented. The activities are adapted to the intentional development of the system and organisation. Programmes for operational management are defined within the framework of strategic management.

\textit{Operational management.} Within the framework of operational management, orders for operational implementation of normative and strategic assumptions are specified. Operational management directs the definition and development of processes in the enterprise.

3.3 OPERATIONAL PROCESSES IN A CONSTRUCTION ENTERPRISE

Operational (business) processes in a construction enterprise can be divided into basic and auxiliary processes. Basic generation of value takes place within the

\textsuperscript{49} Motzko/Girmscheid 2007
framework of basic processes. Auxiliary processes constitute the environment of basic processes which are necessary for their implementation. Chapters 3.3.1 and 3.3.2 present basic information on basic and auxiliary processes.

### 3.3.1 Basic Processes

#### 3.3.1.1 Acquisition

Acquisition consists of processes of identification of clients, or tenders for construction works or services, which are consistent with the objectives of the company (profitability, market-related, competitive, result-based, and environmental). Active and passive acquisition can be distinguished here. Passive acquisition consists of standard proceedings of companies, which search for tender announcements or invitations to participate in electronic exchanges, identify the construction undertakings suitable for bid preparation. Active acquisition includes additional activities, such as introduction of Key Account Management, use of new forms of cooperation with the ordering party (e.g. partnership-based models) or even stimulating demand through development of new business fields. All of these are implemented in accordance with the primary normative and strategic management processes.

#### 3.3.1.2 Bidding

Bidding processes are complex. In the first place, it is necessary to conduct decision-making processes with regard to tender participation (consistency with the corporate strategy and financial management). After a positive decision is made, the service offered is described more precisely (consistency with management of requirements), checking of the basic organisational conditions (consistency with quality and HR management), specification of opportunities and threats (consistency with risk management), as well as analysis of contract conditions (consistency with contract management). Other basic processes in this regard are cost calculation and shaping of prices – preparation of a cost estimate. These are complex processes which are of key significance for a construction enterprise. These are prepared on the basis of tender documents of the ordering party. The cost calculation reflects e.g. the basic financial and technical conditions, production processes, risk assessment as well as the impact of the occupational health and safety, understood as reliable specification of the value of financial expenditures for production and services. These financial values are adapted in the process of shaping the bid price, taking into account the market conditions and the corporate strategy. Effective bid calculation and price shaping are thus decisive for obtaining
and performance of contracts. Thus, basic financial and market-related objectives are achieved (in relation to the competitors) of the construction enterprise, which secure its operation. Operational units, which prepare the bid, prepare appropriate reports for the ICRC (Internal Contract Review Committee), containing, among other things, the profiles of opportunities and risks for the bid. On the basis of the report, the ICRC makes the decision to file a bid or to withdraw from tender. It is recommended that construction enterprises establish committees to review tender contracts, consisting of management members and experienced experts.

3.3.1.3 NEGOTIATIONS/AGREEMENT

Negotiation and conclusion of agreements are the way to specify the details and negotiate the bid until the agreement is concluded, within the framework of legally acceptable methods of communication between the contract parties. It is necessary to take into account the applicable national and European legal provisions on tenders and granting of orders for construction works, which are of decisive impact on the procedures implemented by public or sectoral investors (Directive 93/37/EEC concerning the coordination of procedures for the award of public works contracts or Directive 93/38/EEC coordinating the procurement procedures of entities operating in the water, energy, transport and telecommunications sectors), unlike in the case of private investors. Moreover, the agreement is subject to specific legal principles. For instance, in Germany, these are the provisions of Werkvertragsrechts [Act on commission contracts] § 631 ff BGB [German Civil Code]. An agreement is concluded on the basis of bid placement and acceptance. A significant component of the contract is the form of remuneration, such as the unit price or the flat rate amount for works and services specified. In Poland, construction contracts are assessed in the context of the provisions of the Act of 23 April 231964, the Civil Code and the Building Law Act of 7 July 71994. A contract for construction works is a specific agreement, meaning that the contractor commits itself to commission a facility specified in the contract in exchange for the negotiated remuneration.51

3.3.1.4 DETAILED DESIGN DOCUMENTATION

Usually, it is a complex, interdisciplinary process, in which the participants are architects, designers, construction companies, suppliers and administrative bodies. As a result, a set of documentation in the scale of 1:50 to 1:1 is prepared,

51 Mitrega (2008)
containing detailed descriptions of works and lists of equipment. Depending on the scope of works, the so-called workshop or assembly documentation may be established (e.g. for construction of a facade). In this way, the quality and quantity of individual construction facility components is specified. It should be kept in mind that the detailed design documentation is subject to acceptance of the investor for the purpose of its implementation.

3.3.1.5 Preparation of work processes

Preparation of work processes is a set of activities, commenced after the order is granted. The basic tasks in the field of work process preparation include control of contract documents with regard to their compliance with the bid, final specification of the production technology, defining of the necessary resources, preparation of the schedule of works, preparation of the so-called operative calculation as a base for controlling processes (for detailed information see chapter 4.1) and the project supervision at the implementation stage. This should take place strictly in consultation with the project management (detailed information can be found in chapter 4.2).

3.3.1.6 Construction

3.3.1.7

During the construction phase, production processes are implemented which transform the documentation (non-material) into a real facility (material). To this end, it is necessary to attain a specific level of organisation of processes (works). Organisation allows for maintaining of balance between shaping of processes (defining and implementation of processes) and assessment of processes (see figure 3.3). The implementation processes and the way they are reflected in specific process characteristics (see chapter 2.3) are subject to continuous mutual influences, generating the so-called control system (permanent control, comparing of the plans with the actual condition and acting if any deviations are found). Thus, it is necessary to ensure a complex and simultaneous view of components that are of significance for implementation, such as the documentation, operational means, materials and workforce, as well as parameters allowing for assessment of the process, such as costs, timeliness and quality.
3.3.1.8 ACCEPTANCE OF WORKS AND THE STATUTORY WARRANTY PERIOD

The work acceptance process is of key significance as it finalises the contract. It confirms completion of the subject of the contract, authorising the contractor to claim the remuneration and establishes the statutory warranty period for potential defects. For instance, in Germany, acceptance of construction works by the contractor is conducted on the basis of BGB (the German Civil Code) in association with VOB/B (German standardised conditions of ordering and performance of construction works), leading to the following situation:

- Transfer of responsibility associated with the facility accepted from the contractor to the ordering party. Until acceptance, the contractor must protect the facility completed against damages. After acceptance, this obligation is shifted to the ordering party.
- Payment of remuneration. The ordering party is obliged to pay a remuneration for the works performed.
- Until acceptance, the contractor is obliged to prove the compliance of the works performed with the contract. If any defects are found after

---

52 Motzko (2006)
acceptance, the ordering party should prove that these originated through the fault of the contractor.

- Commencement of the statutory warranty period. The contract goes from the construction performance phase (commitment of the contractor to commission the facility as specified in the contract) to the statutory warranty phase.

It is also necessary to distinguish between acceptance of completed works by the ordering party/investor and acceptance by administrative bodies of individual scopes of works (e.g. the fire service, the public health institute, the Labour Inspectorate etc.).

### 3.3.1.9 Use and Change of Condition of the Facility

The phase of operation is usually the longest period in the life cycle of a construction facility. In order for this phase to progress appropriately, it is necessary to develop adequate management methods which will encompass all tasks with regard to technical, infrastructural and economic spheres, as well as spatial development. During use and operation of the facility, modernisations, repairs, renovations, regenerations, redevelopments, developments and other activities may be conducted. All these processes should be appropriately correlated with the life cycle of a given facility. There are many models of life cycles of a construction facility. Presented below is an example of a three-phase model\(^{53}\) (see figure 3.4).

\(^{53}\) Giesa (2010)
Three phases are defined in this model:

Phase PH 1 "Design and implementation" includes the processes related to the undertaking, associated with development of development ideas (integration of basic elements, such as location, capital and operation concept), design, preparation of detailed design documentation and implementation of construction. The expenditures of this phase are of single-time nature. Phase PH1 is the project phase.

Phase PH 2 "Operation" is the facility phase. Usually, it results in a combination of various states, such as operation, uninhabited space, modernisations, repairs, renovations, regenerations, redevelopments and developments. The operation profile may also change, resulting in substantial changes in the condition of the facility, as well as in the necessity to obtain a permit of an administrative body. The expenditures generated in this phase are cyclical. Depending on the condition of the facility, this phase may also generate cyclical revenues.

---

54 ibidem
55 Diederichs 1994
Phase PH3 “Re-use” (new project phase) includes the components of regeneration, possibly demolishing or disassembly. Within the framework of regeneration, all building components (excluding the shell) may be raised to a new standard. The mode of operation of the facility is usually maintained. An alternative is demolishing the building, which serves as a motivator to prepare a new development project.

3.3.2 AUXILIARY PROCESSES

3.3.2.1 RISK MANAGEMENT

On the basis of legal provisions, companies are obliged to introduce appropriate risk management systems (RMS). One of the significant aspects of these is early identifications of threats to operation of the enterprise.\textsuperscript{56} These are, among other things, due to the dynamics of the business environment (see figure 3.5), which is associated with threats and opportunities. Responding to potential threats is one of the basic functions of good company management. The dynamics of the environment can be systematised as follows:\textsuperscript{57}

- Changes in economic trends: visible within the framework of such indicators as inflation, changes in demand or number of bankrupt companies. For instance, in Germany, a decrease in investment activities in the public sphere has been observed for many years, to which companies may respond by narrowing their activity to specific product and market segments;
- Structural changes: for instance, globalisation of markets, which is reflected, among other things, by intense emergence of unexpected competitors.
- Random events: sudden changes and events, such as natural disasters, stock exchange fluctuations, threat of war activity or amendment of the law. Lately, natural disasters have led to technical disasters that, on the other hand, greatly influenced the capital markets.

\textsuperscript{56} Minasowicz (2008)
\textsuperscript{57} Wurl (2002)
The risk management dimension, which is associated with existence of the enterprise, is decisive for its categorisation in terms of management and auxiliary processes.

Risk management as a process can be divided into six partial processes: identification, assessment, classification, control, calculation of risk costs and risk controlling (see figure 3.6).

---

Figure 3.5. A construction enterprise and dynamics of the business environment\(^{58}\)

\(^{58}\) Motzko (2003)
Risk identification is aimed at full specification of the potential threats. Risk assessment and classification is applicable to specification of the probability of emergence and the scope (extent of damages) of a dangerous (disadvantageous) event.\textsuperscript{60} \textsuperscript{61} On the basis of the above, taking into account readiness to undertake risk and the applied risk management strategy of a given company or construction project, resources are defined, which are necessary to control the risk. Risk can be controlled using e.g. the following means:

- Shifting and limiting of risk, e.g. through commercial agreements or conditions;
- Separation of risk, e.g. by broadening the scope of recipients (risk of sale);
- Risk compensation e.g. by diversification;
- Risk division, e.g. through involvement of many parties in completion of a task (establishment of consortia and workgroups);

\textsuperscript{59} Girmscheid/Motzko (2007)
\textsuperscript{60} Minasowicz (2009)
\textsuperscript{61} Minasowicz (2005)
• Risk insurance, e.g. on the basis of insurance premiums;
• Risk protection, e.g. by establishing reserves.

The risk management process should be implemented constantly. Upon every shift from a partial process to a partial process in implementation of works, the potential threats should be subjected to risk controlling.

Detailed information on the process can be found in manual M8 “Risk Management”.

3.3.2.2 QUALITY MANAGEMENT

Quality (Latin \textit{qualitas}) are various, specific, distinguishable features of objects or services\textsuperscript{62}, such as their shape, colour, durability, smoothness or smell. It is necessary to distinguish between the quality of the project and the quality of the facility (analogous to distinguishing between the project phase and the facility phase, referred to in chapter 1). In terms of project quality, we are speaking mainly about maintenance of the project parameters, such as objectives, organisational structure and organisation of the course of works, along with the flow of data, information and decisions, costs, deadlines or parameters of services. The facility quality pertains to a completed construction facility, including such parameters as sustainability, comfort, durability, usability, image etc. In order to ensure the operational achievement of various quality parameters, companies introduce quality management systems which are usually visibly interdisciplinary. Normatively, these systems are a result of introduction of various ISO 9000 standards, mentioned already in Chapter 1. Historically, regulations in this regard appeared as early as in §§ 229-233 of the Code of Hammurabi or in the work ”De architectura” by Vitruvius\textsuperscript{63}. Quality management systems at a company should be subject to audits and certification to make sure that their effectiveness is verified independently. In the context of quality, it is necessary to underline the issue of safety of technical and engineering facilities; their failures may be of serious consequences to the natural environment, such as nuclear power plants. Technical safety must encompass the entire life cycle of a construction facility and the phases of planning, implementation of construction, use and demolition.

Chapter 4.6 of this manual discusses in more detail the issue of quality management from the perspective of the construction project managers.

\textsuperscript{62} Führer/Grief (1997)
\textsuperscript{63} Vitruvius
3.3.2.3 Management of the Client’s Order

The term *requirements engineering* has been defined by Glinz\(^{64}\) as:

- Systematic, disciplined and quantifiable proceedings during specification, that is, defining, describing and verifying the system requirements;
- Understanding and describing the needs and requirements of clients;
- Specification and management of the client’s order to minimise the risk of development of systems which are of no advantage to clients or not adapted to their needs.

Management of a client’s order may thus consist of partial processes of defining, documenting, agreeing and validating of requirements and management of these requirements\(^{65}\). Until recently, software engineering was the domain for management of the client’s order. However, in the process conglomerates of construction undertakings, characterised by multiplicity of decisions and division of work, it is necessary to apply requirements engineering. The investor formulates their expectations with regard to the construction facility, and the architect/designer, along with the construction facility, implement these guidelines within the framework of the construction project. Specification of target components (a catalogue of objectives of the construction facility) should thus be taking place within the framework of a structured process of designing (planning) of objectives.\(^{66}\) For the purposes of management of the client orders in construction, the ETH (Federal University of Technology) in Zurich\(^{67}\) has devised a phase-oriented, module-based procedure (see figure 3.7). The process chain starts with module process 1 “Specification of requirements”, and it is conducted from the developer study phase to the detailed documentation preparation phase. The expectations are divided into requirements of the users, of the investor, requirements associated with the location/construction site, environmental requirements, standards and legal provisions, project and implementation requirements. These categories of requirements can be applied selectively to each stage of the planning process; however, requirements of the users as the basic variable are significant throughout all project stages. Within the framework of the module process 2 “System integration” during further design, specification of the facility system is devised on the basis of the requirements defined during the module process 1 (target vector) until specification of the final parameters of the

\(^{64}\) Glinz (2008)
\(^{65}\) Grande (2011)
\(^{66}\) Koch (2010)
\(^{67}\) Krönert (2010)
facility components. In module process 3, “Cost specification”, costs are established in relation to stages, at the precision level, which is currently attainable. Financial expenditures should include the costs of the facility life cycle (construction costs, costs of use, regeneration or demolishing etc.) and costs of alternative solutions. In the module process 4, “Optimisation”, all system functions are integrated, and in the final module process 5 “Control of objectives”, compliance with the established parameters (objectives) is verified.

Figure 3.7. Collective presentation of content-based guidelines for processes in requirements engineering

68 Krönert (2010)
3.3.2.4 MANAGEMENT OF HUMAN RESOURCES

Employees largely determine the success of the company. Human resources management is thus one of the decisive, basic corporate functions. A particularly significant requirement for sustainable management of human resources is integration of the economic objectives of the company (e.g. disposal of human resources adapted to tasks, increased production capacity), social objectives (social justice in the company structure, legal provisions on collective agreements) and individual objectives of employees (workplace safety, professional development perspectives, raising of qualifications). In construction, one of the industry branches which is still dominated in many aspects by manual work, another significant component is ergonomics, based on creation of work systems that are employee-friendly.

Systematisation of tasks in terms of human resources management can be conducted on the basis of Harvard approach, consisting of:  

- Creation of systems for management of human resources;  
- Management of employees and teams.

Creation of human resources management systems includes processes that are of primary importance (the plane of the enterprise) and offer no visible individual references. These include generating employee flow systems (planning of demand, recruitment, development, dismissal), and remuneration systems (assessment, remuneration). Employee management includes processes which can be directly referred to individuals. A significant aspect is interaction between employees or groups of employees and the management. New challenges in this regard include the mode of treatment of elderly employees, gender issues and health care management.

In association with human resources management, it is necessary to mention the special role of construction managers and foremen on the construction site. These people are largely responsible for the success of a construction project. The scope of their responsibility includes many aspects, such as:

- Responsibility for the technical result of construction;  
- Responsibility for economic result of construction;  
- Responsibility for occupational health and safety on site;  
- Responsibility to supervision offices and to the investor;

---

69 Stock-Homburg (2010)
- Responsibility for employees with regard to proper disposal of the human resources.

Table 3.1 below presents the types of requirements defined for the construction management.

<table>
<thead>
<tr>
<th>Management and technical requirements in construction</th>
<th>Specialist and technical requirements</th>
<th>Requirements with regard to behaviours</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Ability to control the undertaking</td>
<td>- Good technical educational background</td>
<td>- Strategic and analytical thinking</td>
</tr>
<tr>
<td>- Organisational skills</td>
<td>- Familiarity with construction materials</td>
<td>- Ability to speak expressively</td>
</tr>
<tr>
<td>- Knowledge of the law (building law, civil code etc.)</td>
<td>- Familiarity with standards</td>
<td>- Assertiveness</td>
</tr>
<tr>
<td>- Cost estimation</td>
<td>- Familiarity with processing technologies</td>
<td>- Resistance</td>
</tr>
<tr>
<td>- Ability to process data electronically</td>
<td>- Familiarity with construction machine capabilities</td>
<td>- Ability to solve conflicts</td>
</tr>
<tr>
<td>- Knowledge of organisational links</td>
<td>- ...</td>
<td>- Ability to work in a team</td>
</tr>
<tr>
<td>- ...</td>
<td></td>
<td>- Ability to make decisions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acquiring knowledge</th>
<th>Learning behaviors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.1. Kinds (types) of requirements for the construction management

In the process of creation of organisation of construction undertakings, it is necessary to specify very carefully the personal composition of the construction management team, in accordance with the time loads associated with individual tasks. Figure 3.8 presents a qualitative approach to these factors.

---

70 Werner (2001), s. 63
Figure 3.8. Factors that influence expenditures associated with the construction management

Within the framework of the bid calculation, it is necessary to conduct an analysis of the structure of tasks of the construction management, assigning the appropriate cost values to them. It is necessary to take into account the excessive or insufficient work loads of employees.

Human resource management includes a number of other processes, aspects and partial components. However, these are not discussed in detail in this manual.

3.3.2.5 CONTRACT MANAGEMENT

Structures usually constitute fixed assets of high value; therefore, contracts for construction works, in comparison with ordinary consumer goods, are concluded for large amounts. The production of individual structures in construction, referred to above, leads to conclusion of individual contracts which are then performed within the framework of construction projects of complex organisational structure. Not in all cases, the ordering party concludes a contract with the contractor for specific individual scopes of works. Sometimes, they prefer to sign a “turnkey” contract, which requires cooperation between multidisciplinary design teams.

ibidem
representing the ordering party and the contractor. Apart from construction contracts, the ordering party concludes design contracts with architects and designers. The building contractor additionally concludes contracts with subcontractors or suppliers of materials and equipment; possibly, also with designers. These complex contractual arrangements are associated with amendments, often encountered in the construction industry. These include:

- Changes in the scope of works or additional works;
- Changes in the circumstances, due to which construction works cannot be conducted as specified (e.g. disclosing unexpected soil structure);
- Disruptions of the construction works, e.g. due to delays in obtaining building permits.

Such cases may lead to signing of annexes with regard to the time and scope of works which are to be conducted constructively.

Figure 3.9 shows constant circulation and correlations between flows of data, decisions, goods, financial means and other variables between the project parties. Circulation and interaction are regulated by specific organisational links. The definition of organisational links is based on applicable contracts between the parties involved in a construction project, on technical and legislative conditions or information intentions. In the area of legal relationships, public-private relationships are established between the ordering party and the approving body, while private-legal relationships are established between the ordering party and the contractor. Contracts for construction works or contracts for commission are concluded between the ordering party and the contractor or the designers/architects; the ordering party and users of the facility usually conclude lease agreements. Thus, management of contracts is one of the key auxiliary processes.
Inter-organisational links may be defined in terms of shifts between the decision-making plane (e.g. the investor, official, offices) and the executive plane (e.g. the general contractor). Intra-organisational links may be established within planes, e.g. between the general contractor and the subcontractors for individual units of works.

The following processes are part of reliable contract management:

- Checking completeness and compliance of the tender documentation and contract conditions;
- Analysis of risk in contracts;
- Analysis of organisational links based on the contract;

\[\text{\cite{MotzkoLohr2010}}\]
• Monitoring of variables circulating between the parties to the extent applicable to the contract;
• Detailed documentation of important events, particularly with regard to amendment of contract provisions;
• Control of annexes to the contract;
• If necessary, ordering services of experts.

Performance of contract management tasks requires specific interdisciplinary knowledge. Apart from specialist knowledge in specific areas of engineering, it is necessary to attain knowledge and experience in construction contracts (e.g. the FIDIC contract conditions or the standardised conditions of ordering and performance of construction works – VOB in Germany), as well as in finance.

3.3.2.6 CONTROLLING

There are many definitions and concepts of controlling, which range from very narrow functions within the framework of comparison of the planned condition and the actual condition to the basic corporate management component. Controlling itself should be understood as a system which provides the corporate management with tools and information for supervision of day-to-day basic and auxiliary processes, for their control, devising alternative actions and justification of decisions made.\(^{73}\)

An example of the basic management component is the controlling concept prepared by Horváth\(^ {74}\) on the basis of the systems theory, taking into account the practical aspects. Controlling components are the system of design (planning) and control and the system of delivery of information (see figure 3.10).

\(^{73}\) Schultz (2010)

\(^{74}\) Horváth (2008), s. 39 ff.
Figure 3.10. Controlling as a management sub-system

Planning and control. Planning is "systematic, future-oriented consideration and specification of objectives, steps and ways of achieving the goal". It is about designing (future activities which are oriented to specific results. Planning is processing of information (taking into account exchange of information between the involved work positions or organisational units); therefore, it requires the proper supply of information. The result of the planning (design) process is a specific “timetable”, serving as a basis for achievement of the goals defined. The following questions are asked during the design process:

- Were the assumptions made proper and did any unexpected events occur during the plan implementation?
- Was the target impact of the steps planned assessed properly?
- Are the means planned available and being implemented?
- Are the participants following the plan? 

---

75 Horváth (2008), s. 39 ff.
76 Wild 1979, s. 13
77 Horváth (2008), s. 155 ff.
78 ibidem
Planning as a process encompasses the components of problem analysis, generation of alternatives, assessment of variants and decision-making. The time dimension of design may be either short-term (operational planning), medium-term (tactical planning) or long-term (strategic planning).

Control (or plan control) is a comparison of the planned and achieved values. This allows for determining whether the goal defined has been attained and whether any deviations occurred between the planned and implemented state. Control thus supports the planning process. It can be divided into three areas:

- Control of assumptions – it is controlled whether the decision-making bases devised within the framework of planning are applicable. If not, an adjustment is to be made;
- Control of results – by comparison of the planned and actual status, the degree of achievement of objectives is verified. Through analysis of deviations, it is necessary to determine the cause of differences or lack of differences between the planned and actual status;
- Control of the process – aimed at verification of activities or qualifications applied to the company or project.

Delivery of information. One of the definitions of information states that it is knowledge of the circumstances and events, used to achieve a specific objective. Management of a company or a construction project requires the appropriate information.

The most important features of demand for information include:

- Kind,
- Quantity,
- Relevance,
- Presentation format,
- Compacting,
- Frequency,
- Precision,
- Reliability,
- Significance,
- Timeliness,
- Quality,
- Application,
- Measurability,
- Costs and
- Safety.

Through filtering, compacting and intentional distribution, information is to be aggregated to establish conglomerates that are as meaningful as possible. It must be relevant also for the short-term planning and control cycles, and their validity and

---

79 Schultz (2010)
80 Gabler
81 Horváth (2008), s. 332 f.
quality must allow for solving of problems. During exchange of information between the process participants, there must be precise understanding of the content.\textsuperscript{82}

In the context of delivery of information for controlling purposes in construction, it should be stated that in practice, there is a discrepancy between the requirements of the construction management with regard to availability of analytical data from comparison of the planned and actual condition and the designation of controlling tools. Figure 3.11 presents the results of a research project on controlling of deadlines and costs. It can be seen that there is a substantial difference in the periods between the practical implementation on the construction site, based on the needs of the construction management, and the determinants of the controlling system. Thus, in practice, systems applied are adapted to individual needs which, however, are unable to communicate with the superior tools in the enterprise.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{chart.png}
\caption{Discrepancy between controlling guidelines and implementation in construction projects} \textsuperscript{83}
\end{figure}

\textit{Control.} Control can be understood as intentional impact, exerted on the system, in order to achieve planned system behaviour. With reference to the construction projects, this is about maintenance of the deadline, quality, quantity, cost and other values, specified in the contract. In order to avoid economic problems associated with competition in construction projects, planning and production, as well as the construction works performed, should be constantly supervised in terms of deviations from the goals established and actively controlled on the basis of analysis of deviations. This issue will be discussed in more detail in chapter 4.1.

\textsuperscript{82} Horváth (2008), s. 320
\textsuperscript{83} Heim (2002)
3.3.2.7 IT MANAGEMENT

Information technology can be understood as a resource used for processes at the company, which is thus of high strategic and operational importance.\(^8^4\) It is applicable anywhere, in various areas of the company, for instance, the products themselves, operational processes and the superior business models. The IT offer portfolio for Volkswagen corporation has been prepared very well, as it is highly representative (see figure 3.12):\(^8^5\)

- Increasing effectiveness and development through client-orientation and creation of innovative products, establishment of a network of organisational units and external partners and integration of all digital and IT process along the value creation chain (application of customer relationship management);
- Increasing efficiency through standardisation of operational processes for brands and domestic branches and preparation of integrated, cost-effective IT systems (use of portals);
- Increasing efficiency through combination of resources and standardisation of IT systems and flexible management of resources (management of global resources through IT-governance).

![Figure 3.12. Example of an IT offer portfolio\(^8^6\)](image-url)

---

\(^8^4\) Mühleck (2006)
\(^8^5\) ibidem
\(^8^6\) Mühleck (2006)
The same can be referred to the field of construction. The IT technology challenges, however, are more complex due to manufacturing of unique products. A detailed discussion on the problem of digital processes in construction can be found in manual “Computer Methods in Construction”.

### 3.3.2.8 COMMUNICATION

Communication processes in an enterprise (a project being implemented) are complex. They are commenced in the area of relations between the enterprise and the broadly understood environment – the stakeholders or external institutions, to which e.g. the enterprise is obliged to report. In the enterprise itself, there are intense communication processes as well, for instance, consulting in the field of corporate strategy at various levels from operating management to normative management. Interpersonal communication processes within the framework of organisation of construction projects are discussed at the end of this chapter. As has been mentioned, implementation of construction projects usually takes place in complex organisations, which are characterised by dense communication processes. The term “communication” comes from the Latin word *communicare*, which means: to share, to combine, to deliver a message to somebody. In this context, communication is of constructive-integrating, and thus, to some extent, engineering nature. In relation to a construction undertaking “to share” means that all participants of the project, while retaining their identities and social or economic roles, do their best to complete the construction tasks. The offices issue building permits on the basis of the applicable legal provisions and companies do their best to engage in business activity to attain the appropriate profit.

Organisation of construction projects is characterised by numerous conflict situations which, among other things, are due to the fact that the project participants function like “black boxes”, meaning that their behaviours are determined by complex autoreferential operations within the framework of their competences. These are a result of various forms of pressure and restrictions, applied to individual project participants. As a result, despite their efforts, they remain closed towards each other.
Figure 3.13. Complex interpersonal communication of the construction project participants

Differences in perception of interpersonal communication by participants of the construction projects are illustrated in figure 3.13. Depending on the perspective of the task to be implemented, they can be interpreted variously. To explain the content of the drawing, it is necessary to note that in the opinion of the author, for construction processes, apart from such values as space, time and quantification (arrangements) which are used to organize the content in the human mind, another tool required is logic, which confirms the correctness and coherence of processes. Spatial systematisation of a given project is determined through quantification (arrangements) as the organising component. All this requires also a certain kind of intuition, as well as emotions. In interpersonal communication, it is always necessary to take into account the individual potential of the project participants. In stress situations, which are often encountered in project organisation, generating and receiving messages is a complex process. Every message generated by a project participant results in a specific response of the recipient, which can be explained, for instance, on the basis of the message content features according to the “four ear model” of Schulz von Thun:

- The content = the subject of the message;
- The appeal = activity which the sender wants to be done by the recipient;

---

87 Motzko (2008)
88 Schulz von Thun (2007)
The mutual relation = attitude of the sender towards the recipient;
Self-statement = manifestation of the state of the sender.

These components, among other things, due to their individual character, make interpersonal communication a very complex issue. The first theoretical attempt to solve this problem can be made using the Media Richness Theory of Daft and Lengel\textsuperscript{89}. This theory has been criticised mainly due to superficial analysis and shifting results of dyadic interaction to organisations. It is also possible to use the Media Synchronity Theory and the Media Featured Theory, which take into account such aspects as the ergonomics of media used for communication. As a result, it is recommended that computer systems are used to support the communication processes. This issue is presented in manual M10.

### 3.3.2.9 Occupational Health and Safety

Unification of Europe has lead to a significant change in the framework conditions of occupational health and safety, both from the perspective of investors and construction companies. The basis for this unification is formed by directives 89/391/EEC and 92/57/EEC for temporary or mobile construction sites. It is necessary to keep in mind the transmission of these directives into the domestic legislation and compliance with the legal provisions applicable on a given market; in Poland, among others, these are the Labour Code and the Building Law. Both the investor and the construction company performing the contract, should have at their disposal qualified staff and competent management, as well as the appropriate machines and equipment necessary to conduct the construction works. This is associated with the fact that employees at time-limited or mobile construction sites are particularly threatened by serious dangers. According to research conducted by the Federal Institute for Occupational Health and Protection - Bundesanstalt für Arbeitsschutz und Arbeitsmedizin\textsuperscript{90}, dedicated to fatalities in years 1998-2000, the following conclusions can be made:

- Up to 54% of fatal accidents occur on site;
- 42% occur in the construction sector;
- 35% are falls from heights (main accident factor);
- 25.1% of falls are from heights of 10m or more;
- Among the set of causes (there is rarely a situation in which a single cause of the accident can be identified), 95% of accidents are caused by erroneous actions; 53.5% by bad organisation; 10.2% by workplace

\textsuperscript{89} Daft/Lengel (1986)
\textsuperscript{90} Henter/Hermanns/Wittig (2001)
characteristics; 11.2% by technology; and 2.6% by physical or psychological conditions.

A construction site, as a place associated with threats, to which employees are exposed, should be properly planned and documented. In every EU member state, prior to commencement of the works, it is necessary to inform the offices responsible for occupational health and safety (labour inspectorates) of commencement of works, for which a specific safety threshold has been exceeded. It is also necessary to ensure the proper coordination of works. The following principles apply in this regard:

• The investor must always comply with the applicable labour protection provisions (Labour Code) and meet the obligations specified in other acts and directives. On the construction sites, this usually requires hiring an OHS coordinator, preparation of a safety and health protection plan (BIOZ), notifying the appropriate body (Labour Inspectorate) and the designer of the planned commencement of construction works. The investor ensures devising of projects and performance of acceptance of construction works by persons having the appropriate professional qualifications;

• The entrepreneur should follow the labour protection provisions (Labour Code), organise works on the site in a manner that ensures safety and protection of health of the employees and comply with the provisions of the corporate occupational safety regulations. The entrepreneur is responsible for preparation of the documentation, implementation and verification of the analysis of threats for each workplace and the construction site. The employees are obliged to comply with the occupational health and safety provisions at work.

Chapter 4.4 of this manual provides details on occupational health and safety from the perspective of management of the construction project.

3.3.2.10 INVESTMENT PROGRAMMING MANAGEMENT

A typical feature of construction is working on the basis of orders, which means that planning and construction of a structure starts only after the order is granted. The company should have the appropriate work capacity at its disposal, allowing it to respond quickly to individual demands of the client (investor/ordering party). The objectives of the construction project, the time for performance of works (design and construction) and the place of construction are specified by the client. At the same time, a typical feature of construction is division of implementation into fragments, which usually leads to organisational division between planning
and implementation of a construction project. There are many typical organisational links (see subchapter “Contract management”).

The design processes in construction are usually non-linear and cyclical (see figure 3.14). This means that over the time span of the project, information gathered by the designer may impact on the design process, which results in continuous modification of the design condition. Such phenomenon is not always effective.

Figure 3.14. Cyclical diagrams of progress of construction works in the investment programming (design) process⁹¹

The investment programming processes in construction are subject to intense interactions between various disciplines, such as designing the load-bearing structure and soil mechanics, technical equipment and installations, physics and acoustics of the structure, sound insulation, surveys and other works necessary for overall, professional design of a facility. The design should be prepared in accordance with a quality standard which will allow the investor to obtain a building permit. This requirement has its technical, as well as a legal dimension. Figure 3.15 shows interactions between various scopes of design, using a simple example.

⁹¹ Koch 2010
Figure 3.15. Examples of interactions between design disciplines in the planning process \(^{92}\)

\(^{92}\) Motzko/Löhr 2010
Designing is a complex activity which requires specific features and knowledge of the designer (planner). These include:\(^{93}\)

for individual tasks:
- special technical qualifications;
- familiarity with the necessary design tools (material and conceptual),

for collective tasks:
- social behaviours;
- team work skills;
- ability to solve conflicts, to interact with other planning participants;
- coordination and proper treatment of the project participants;
- knowledge of the flow of information and forms of organisation of the project participants;
- familiarity with the resources required;
- familiarity with socialisation and the primary planning systems.

It is necessary to diversify remuneration for design tasks. For instance, in Germany, there is legislation defining the remuneration amounts for design services; the Regulation concerning remuneration for services of architects and engineers (\textit{Honorarordnung für Architekten und Ingenieure – HOAI}).

As for structuring and classification of the planning processes, there is an analogy to the structure of processes, defined for construction enterprises in figure 1.2.

\(^{93}\) Koch 2010
Figure 3.16. The structure of processes in a design enterprise

Management processes in design. The management processes include the basic and strategic processes. The strategic processes include normative, strategic and operational management. The basic processes start with management of the offer/acquisition, after which management of planning of objectives is commenced. Both of these processes are defined as non-design processes, since, apart from the design office, there are external institutions involved, such as the ordering party and a professional designer. Further design management processes and management of the actual planned condition (management of implementation) are aimed at well-structured, coordinated and controlled implementation of the project objectives in accordance with the planning guidelines. Particularly important are the objective planning management and the design planning management. Within the framework of design management, multi-dimensional inspirations (objectives) in the construction process are appropriately directed, qualified by the project participants and objectively specified and structured in accordance with the corporate strategy. It is necessary to define a system of objectives for a
construction project; all project participants will aim to achieve these. Design planning management is aimed at raising effectiveness of the design processes.

Operational design processes. Operational processes in design are divided into basic processes, aimed at preparation of a plan which establishes the basic value, and auxiliary processes. The structure and function of auxiliary processes are analogical to those of construction production processes, presented in Chapter 3.3.2. Basic processes are defined in Figure 3.14 using work stages LP 1 to LP 9, the example content of which can be found in the HOAI (Regulation concerning remuneration for services of architects and engineers - Honorarordnung für Architekten und Ingenieure HOAI). In other cases, the content is to be specified individually.
CHAPTER 4

SELECTED OPERATIONAL PROCESSES IN A CONSTRUCTION ENTERPRISE
(C. MOTZKO, W. MARTINEK, J. KLINGENBERGER)

4.1 BASIS OF OPERATIONAL CONTROL OF PROCESSES

4.1.1 BASIS FOR COMPARISON OF THE ACTUAL AND PLANNED CONDITION

Chapter 3.3.2 explains the basic concepts of controlling. It describes the significance of comparisons between the planned and actual condition for various variables as one of the basic tools necessary for determination and analysis of deviation in completion of processes. This approach will be discussed in more detail with regard to the needs of a construction project.

The formal basis for comparison of the actual condition and the planned condition can be found in managerial accounting, one of the basic components of corporate accounting. In this manual, it is not possible to discuss this issue in detail. The issue has been discussed in the appropriate literature on the subject.

In the first place, it is necessary to clarify the meaning of comparison of the planned and actual condition. Such comparisons are used to contrast the planned statuses and numbers with the actual ones with regard to the quantity, time or other process values in order to analyse the potential deviations. This serves as a basis for determination of funds for modification of the organisation, structure or share of the processes considered in the project, as well as other activities, allowing these
to be controlled. Comparisons of the actual and planned condition are thus a
significant component of project control from the perspective of a construction
company.

The following comparisons of the actual versus planned conditions are usually
conducted in construction projects:

- Comparison of actual versus planned costs;
- Comparison of the actual versus planned economic result of the
  construction project;
- Comparison of the actual versus planned man-hours and machine-hours;
- Comparison of the actual versus planned deadlines;
- Comparison of the actual versus planned consumption of materials;
- Comparison of the actual versus planned quality (the degree of
  achievement of the planned conditions).

Comparisons of the actual versus planned values are conducted periodically.
Comparisons of actual versus planned costs, economic results and man-hours, as
well as machine-hours, are usually conducted in monthly cycles (which are
determined by the accounting processes), while comparisons of actual versus
planned deadlines are conducted in weekly cycles (which are applicable to well
managed construction sites).

It should be noted here that thanks to the application of modern methods of
documenting and reporting of construction works, it is possible to increase the
frequency of comparisons; thus, some of the values can, in fact, be monitored in
real time.  

The basic components of actual versus planned comparisons are:

- The scheduled values: they serve as the starting point for actual versus
  planned comparisons and they are established on the basis of the contract.
  A necessary document here is the contract for construction works,
  including the description of works, designs, schedule of works and other
  arrangements. For all actual versus planned man-hour and cost
  comparisons, it is necessary to prepare an operative calculation (see
  Chapter 4.1.2), in which the planned values will be established, unchanging
  throughout the construction project period (except for situations, in which
  the contract conditions are amended). The scheduled values with regard to

---

96 Motzko/Mehr/Bergmann 2010
timeliness of works are specified on the basis of the work schedule, agreed upon with the investor;

- Planned values: planned values are determined by linking scheduled values (e.g. cost values from the operational calculation) with works performed on the construction site. For instance, determination of planned hours is based on linking (multiplying) the value of expenditures from the operational calculation (planned quantity) for a given scope of works (e.g. boarding of the floor 0.40 h/m²) with the quantity actually implemented on the site (on the basis of a quantity survey);
- Actual values: based on construction site reports (documentation of work progress) and documents of the accounting department;
- Forecast values: an assessment of deviations of the actual condition from the planned condition and a forecast for the future.

The basic actual versus planned comparison is presented in figure 4.1.

Figure 4.1. Basic course of control of construction processes on the basis of actual versus planned comparison

---

97 Pflug (2008)
An example of floor boarding works. Report for one month.

Operational calculation: the expenditure planned for floor boarding was 0.40 h/m².

Quantity performed on site in the reporting period (1 month): 1.000 m² (quantity survey on site)

Planned value: 0.40 h/m² x 1,000 m² = 400.00 h

Actual value: the site reports performance of 1,000 m² of floor formwork, according to the quantity survey, and the man-hour expenditure of 389.00 h

Conclusion: floor boarding works are conducted in accordance with the man-hour plan.

ATTENTION: It is also necessary to analyse the work schedule!

Using the actual versus planned comparison, it is possible to determine whether any deviations can be found from the planned values and their range. On this basis, it is possible to conduct analyses to define the causes of deviations to specify the means for control of processes or their improvement. This can serve as a basis for preparation of a forecast of the future development of the values analysed. Even if there are no deviations of the actual values from the planned ones, it is always necessary to analyse the processes to implement constant improvements. It is necessary to keep in mind the particular significance of the integral correlation between numerical values and their time references.

4.1.2 Basic Controlling of Construction Costs

In order to conduct an actual versus planned comparison of costs and results, it is necessary to prepare the so-called operative calculation. This document serves as a basis for control of processes at the project implementation stage. It defines the objectives of the undertaking from the perspective of the implementing corporation. Operative calculation is a component of managerial accounting, and within the framework of this accounting – of the construction order account (see Figure 4.1.1 and a detailed discussion in Girmscheid/Motzko 2007). It reflects the executive processes in structures that are related to costs, time and quality, it serves as expansion of the bid calculation or its modification after the contract is concluded as the contractual calculation. On the other hand, bid calculation is conducted within the framework of production preparation. Operative calculation
differs from bid calculation in terms of its application and structure. The bid calculation serves as a basis for conclusion and performance of a contract between the ordering party and the contractor. In the case of operative calculation, we are dealing with the cost structure, which is of purely internal nature, which is at the disposal of the project management and the top managerial staff responsible for its development. Within the framework of operative calculation, target values that are of significance for the project are determined, making it possible to analyse deviations during construction with regard to the planned and actual values, thus creating a basis for means of control. Therefore, it is a significant component of project control.

The operative calculation structure in terms of costs is as follows:

- The item structure refers to the bid calculation;
- The costs of individual items are specified according to fixed and variable costs; complex costs are divided according to the type of resources used;
- The structure of individual items can be divided into sub-items, if specific works from a single item are divided into time sections, such as assembly and maintenance of a crane. This allows for creation of a structure that serves as a basis for regular assessment of cost development;
- General construction costs, divided in the bid calculation according to a division key into individual items, are specified separately as the so-called auxiliary items in operative calculation.

Operative calculation in any construction project should be prepared by the enterprise which implements the project, and it should specify the following:

- A transparent, operational structure of target values, mainly the costs, as a basis for process control. This structure should be adapted to the real conditions and characteristics of the task and contain the rates, referred to feasible tasks;
- A detailed structure of costs of all works and reflection of contract modifications which are significant from the perspective of the order;
- Its application leads to in-depth analysis of the cost and result-based situation and values in terms of the project deadlines and quality;
- The cost forecast account, which enforces regular assessment of the project opportunities and threats.

---

98 Girmscheid/Motzko (2007)
The actual versus planned comparison should include at least a numerical comparison (e.g. of costs) and a schedule of works as a unit.

Figure 4.2 presents a graphic interpretation of the actual versus planned construction costs.

![Figure 4.2. Analysis of deviations in the actual versus planned comparison of the construction project](image)

**Figure 4.2. Analysis of deviations in the actual versus planned comparison of the construction project**

The course of costs planned reflects the result of the contract, concluded on the basis of the bid calculation. The real costs (see 4.1.1, example of boarding works) are a result of linking (by a product) of unit costs of a given item from the operative calculation and the quantity of works completed on site. The accumulated costs are costs resulting from completed construction works, based on the corporate accounting documentation. A comparison of these three values allows for determination of whether the costs have been exceeded or saved in relation to a

---

99 Girmscheid/Motzko (2007)
specific moment and for their analysis. On the basis of analysis of deviations, it is possible to forecast the development of costs in the future. Unfortunately, actual versus planned comparisons in construction are conducted too rarely. Current and thus active control of processes is thus not warranted, since some of the processes considered within the framework of the actual versus planned comparison are completed before the control process starts.

4.1.3 BASIC CONTROLLING OF THE SCHEDULE OF WORKS

Construction contracts usually contain the requirement of balancing between defect-free and timely implementation of works. Thus, apart from control of costs, results and quality, a very significant role in construction projects is played by control of deadlines. Contracts for construction works are usually concluded for a specific time period and they often contain provisions concerning contractual penalties if the deadlines specified are not met. Therefore, particular attention should be paid to precise planning of deadlines and actual versus planned deadline comparisons. In this context, coordination of work progress over time should be treated as equally important.

A starting point for comparison of actual versus planned deadlines is preparation of a schedule within the framework of preparation of production, which is to play the following roles:

- In terms of time and space – definition of all planning and completion processes;
- Basis for specification of costs and prices;
- Basis for specification of resources necessary;
- Basis of cost and deadline controlling (costs and results account);
- Basis for disposal and logistic processes;
- Basis for contract controlling;
- The appropriate technical and economic order of tasks;
- Specification of the total time of construction (if not enforced);
- Upon enforced construction deadline: specification of resources;
- Optimisation of progress of construction works with regard to the required production capacity and/or construction time;
- Documentation of planning and implementation.
A schedule should meet specific requirements:\(^{100}\)

- A schedule should be reliable, that is, feasible in terms of technical issues and deadlines;
- A schedule must be clear. It should contain a visible structure of division, order of tasks and a structure of correlations between them. The level of detail should comply with the schedule objective (framework schedule, general schedule, detailed schedule);
- A schedule should be complete, that is, include permits, planning and documentation delivery deadlines, construction production processes, investors’ decisions and other significant processes which influence the deadlines;
- A schedule should be calculable to allow for determination of impact of various events (e.g. by use of network-based methods).
- A schedule should be binding, that is, included in the contract.

A schedule planned in this manner, which reflects the contract conditions, is compiled into internal schedules of the enterprise performing the works (the general construction schedule, detailed schedules for implementation of a schedule or a single type of works etc.). A work schedule contains various other deadlines, which are not significant from the perspective of the ordering party (such as reserves for standstills due to weather conditions, delivery deadlines etc.), specified by the enterprise only for its internal purposes. The procedure for preparation of a contract schedule is illustrated in figure 4.3.

\(^{100}\) Vygen/Schubert/Lang (2008)
Figure 4.3. The contract schedule preparation procedure\textsuperscript{101}

In building practice, detailed schedules are usually prepared every week to ensure proper control of processes on the construction site. Depending on the situation, individual works, even those which are included in the documentation on everyday basis, are analysed as necessary. It is important that the actual versus planned comparison of deadlines is associated at least with the comparison of costs and quality.

\textsuperscript{101} Motzko (2009)
4.2 PREPARATION OF WORK PROCESSES

4.2.1 CLASSIFICATION OF WORK PROCESSES

The term ”construction” can be defined in many ways. However, approaching the issue in a general manner, it can be said that ”construction” is an activity which results in intentional and thought-out division of space, which allows for shaping of a structure that satisfies a specific need. This division is obtained by creation of appropriate partitions which, depending on the type of structure, constitute the set of construction components. Each component is a result of implementation of a number of intentional tasks, activities of various levels of complexity which, in general, can be referred to as construction processes. These processes have been defined and systematised quite well. In general, this systematisation is as follows.

The basic term, referring to any human activity aimed at material transformations is the production process, which encompasses all operations and activities, as well as work movements associated with manufacturing of a product, its part or component. A more narrow term is the technological process, which is a methodical production process, encompassing all working operations, resulting in physical and chemical transformation of the product, its part or component.

A technological process, referring to construction, is a construction process – a set of technologically correlated working operations carried out on the construction site or within the facilities necessary to construct a structure or its part.

Construction processes can be divided according to various criteria, and the level of their complexity allows for differentiation between simple and complex processes.

A simple construction process is a process consisting of technologically correlated work operations performed by employees of the same trade, or a single-task machine (e.g. construction of reinforcement of a ferroconcrete beam).

A complex construction process is a construction process consisting of various simple work processes which are strictly correlated technologically and organisationally, aimed at production of a specific construction component (e.g. construction of a ferroconcrete beam, which consists of the following simple
processes: installation of formwork, assembly of reinforcement, laying of concrete mix and form stripping).

According to their technological properties, the following are distinguished:

- **Preparatory processes**, aimed at ensuring the appropriate conditions for implementation of basic and auxiliary processes; specific preparatory processes for most tasks are transport processes, aimed at delivery of materials, prefab components, products and equipment to the place of installation;
- **Basic processes**, conducted directly on the site to construct the basic structure components;
- **Auxiliary processes**, conducted outside the facility or directly within the constructed facility, which are an integral part of basic processes, but are not related to direct installation of materials, prefab products or components.

From the perspective of nature of processes, we divide them into:

- **Cyclical processes**, during which individual work operations are repeated in the same order;
- **Continuous processes**, which are characterised by continuity of analogous work operations within strictly defined time intervals.

Technological processes are not uniform components, which is suggested by their definition, but they are divided into certain components. These include operations, activities and work movements.

A work operation – is an organisationally indivisible, technologically uniform part of the construction process, characterised by:

- Unchanging composition of the crew;
- Use of the same tools;
- Installation of a single type of material, prefab product etc. (e.g. cutting of reinforcement steel, assembly of the reinforcement frame etc.).

A work activity is a set of movements constituting a separate activity, characterised by specific task and usually constituting a fragment of a work operation (e.g. measuring a rod to be cut, moving a measured rod for cutting, cutting the rod etc.).

A work movement is the smallest fragment of the production activity, which involves touching a tool, device, construction component or prefabricated product by the employee to move it or turn it (e.g. grasping the rod, attaching the meter, marking of the cut location etc.). A diagram is presented in figure 4.4.
In practice, construction processes can be grouped for construction of a single component (pole, beam etc.) or grouped according to any other property selected. This allows for precise defining of the terms; construction works, or sets of construction processes, resulting in construction of a structure or its part, its reconstruction, rebuilding, development or demolition.

It should be kept in mind that construction processes are always aimed at a specific component or set of components. The term “construction works” includes the potential possibility of organising the processes as necessary in a given case.

Figure 4.4. Methodology of operation during construction of structures

Usually, construction works are divided according to:

- degree of advancement of construction (zero state, raw state, shell, finishing, equipment),
- materials used (earthworks, brickwork, concreting etc.),
- craftsmanship specialisations applied (plastering, roofwork, paper-hanging, tiling),
- construction type (large structures, road construction works, bridge construction, etc.),
- special equipment used (ramming, caisson building etc.).

4.2.2 BASIC COMPONENTS OF CONSTRUCTION PROCESSES AND THEIR CONDITIONS

Implementation of a building structure, which is a set of construction components, requires the establishment of an appropriate set of construction processes. Obviously, every construction facility can be built in many ways, creating various sets of processes. These series can be divided into three chronological stages.

1. Processes dedicated to production of the necessary materials, products and potential prefabricates to create the structure of the facility, installations and finishing;
2. External transport processes (from production plants to the site) for materials, products and prefabricated components;
3. Assembly processes conducted on the site.

The processes belonging to all of these stages must be implemented in the appropriate time and place.

Efficient implementation of construction and assembly processes depends on one hand on the technological quality of construction components, and on the other hand on the components of the input vector, which consists of the following production factors, usually divided into three groups:

- Construction materials;
- Work (performed by employees);
- Operation of equipment.

A diagram is presented in figure 4.5.
### Figure 4.5. Conditions of activities for preparation of a construction component.

In every activity of this kind, the construction component, presented in the construction design, is a result of intentional, coordinated action aimed at taking into account such conditions as:

- the needs and customs of the community, for which the facility is constructed;
- the existing legal provisions;
- concept of the designer.

From the perspective of activities aimed at construction of a facility (component), its basic property is its technological quality, or the set of its properties, which suggest application of certain processes for performance of this component, or application of the appropriate technology (understood as the applied or proposed method of production or processing of raw materials, materials and products).

Building practice has shown that for efficient implementation of construction works, particularly typical ones, specific sets of processes which are devised, prepared and implemented have emerged. Such sets of processes are known as the construction technologies. In other words, a construction technology is the technology of preparation of construction components and construction, taking into account the specific materials and modes of solving and implementation of...
construction of structures and the entire construction system along with ensuring the tasks necessary.

In history of construction and in practice, four basic types of construction technology can be distinguished, consisting of the following stages:

- Construction technology type I includes: extraction of raw materials, processing of raw materials, transport, storage on the site and internal transport and use for construction;
- Construction technology type II includes: extraction of raw materials, changing of physical and chemical properties, transport, storage on the site and internal transport and use for construction;
- Construction technology type III includes: extraction of raw materials, changing of physical and chemical properties I, transport, storage on the site and internal transport and use for construction, changing of physical and chemical properties II;
- Construction technology type IV includes: extraction of raw materials, processing into prefab product, transport, storage on the site and internal transport and use for construction.

Practically all of the construction technologies used nowadays are a continuation of these diagrams or a mix of these. Let us examine the most popular ones:

- Structures made of construction soil (excavations and embankments) are constructed using processes included in technology type I;
- Bricked components are made using processes of technology II (production and laying of bricks) and processes of technology III (laying mortar);
- Ferroconcrete (concrete components) are made using technology IV processes (assembly of formwork and reinforcements) and technology III processes (laying concrete mix);
- Structures are assembled using processes of technology IV.

Sets of activities performed on the construction site during construction of a component (facility) within the framework of the same technology may also differ. The differences may be due to:

- The general concept for implementation of the undertaking and time limitations due to contract deadlines;
- Location of the place of implementation of processes e.g. in relation to traffic routes;
- Typical properties of the production factors used.
The general concept of implementation of an undertaking consists of many arrangements; among other things, for every complex construction process (resulting in emergence of a construction component), it should specify the type of processes to be performed directly on the site and the length of series of these simple processes. For years, there has been a visible trend of moving as many processes as possible to plants outside the site. The first such processes included the processes of production (prefabrication) of steel components for assembly, the processes of production of concrete prefabricates, production of concrete mix, reinforcement components etc. This phenomenon has shortened the complex production processes and it can be forecast that the share of technology of type IV in implementation of construction undertakings will increase.

It is obvious that the composition of the set of processes depends on location of traffic routes. It is always necessary to analyse whether the operating routes require modifications or additional equipment for the processes implemented, particularly in the places of loading, reloading or unloading.

The production factors presented as a set of materials necessary, work to be performed and operation of the set of machines and equipment, require a more thorough analysis.

Construction materials used in the implementation process influence greatly its composition. In the first place, this pertains to the degree of processing and adaptation of the material for use in a specific process. For instance, the process of production of concrete mix is implemented somewhat differently if fractional aggregate is supplied to the concrete mixing plant, in comparison with delivery of ready aggregate mixes. Another issue which requires some adjustments of the production process, is the quantity of materials used. Usually, in the case of small consumption of a given material, it can be treated differently from material used in large quantities. Changes in some processes (e.g. painting) may be due to the material being supplied in a package different from planned.

The issue of expenditures caused by operation of the set of machines and other equipment used also influences the processes mainly due to:

- The composition of set of machines and equipment used (or available);
- Technological properties and parameters of machines selected;
- The applied mode – diagram of work of individual machines and sets of machines;
- Training and qualifications of machine operators.
A production factor, which results in the same efficiency of various variants of sets of processes due to differences caused by materials and equipment, is work of people, which is the most flexible factor in the structure, most easily adjusted and adapted, providing that the company has sufficient resources in this regard. In reality, work expenditures in the production process are generated by teams, work gangs, which must be selected carefully. Their composition is based on:

- The required amount of work due to technological properties of a given component;
- The required amount of work due to materials, machines and equipment used;
- Qualifications of company employees;
- The set of economic and non-economic motivators used;
- The rules of safe work applied.

In the light of the conditions presented, good preparation of production processes is a difficult and complex task. It is somewhat facilitated by growing specialisation, as a result of which the general contractor entrusts the specific parts of the process to specialist companies. Such companies specialise in implementation of specific processes, having at their disposal the appropriately qualified and experienced staff and reliable equipment.

### 4.2.3 Procedures of Preparation for Implementation of Construction Processes

#### 4.2.3.1 Introduction

Preparation of construction of components, or launching a given task in a given situation, requires:

1. Analysis of the task, its nature and scale;
2. Preparation of a list of basic simple processes, their correlations to establish the complex process;
3. Preparation of a list of auxiliary processes to support the basic processes;
4. Defining conditions of proper performance of simple processes within the framework of the complex process being performed;
5. Defining the scope of individual task stages;
6. Selecting equipment and planning work of each type and equipment units;
7. Establishing the necessary employee qualifications and selection of work gangs;
8. Defining duration of performance of individual tasks within the framework of stages defined and ensuring their synchronisation in accordance with the complex process diagram;
9. Ensuring the delivery of materials and equipment at the right time and place.

In practice, in many cases of implementation, the diagram presented may be very much simplified due to the existing technical, technological, organisational and economic conditions. The arrangements made should be recorded in the appropriate document which, depending on the scale and complexity of the task, may be: an instruction, a procedure, a technology sheet, a project of technology of performance of works or a project of technology and organisation of construction.

4.2.3.2 Preparation of performance of soil components

Components performed using construction soil are:
- excavations, or space of the appropriate size and dimensions, attained by removal of construction soil;
- embankments, or components made of construction soil of the appropriate size and dimensions.

To prepare the implementation of these components, it is necessary to:
I. In the case of excavations:
   a) Gather preliminary information, that is:
      - establish the parameters of soil in the place of the future excavation (at least its type and category);
      - classify the excavation (wide, narrow, cavernous) and analyse its shape and dimensions;
      - define the place for removal of soil (distance from the excavation, shape, road types, entry);
      - recognise the possibility of emergence of factors hindering work and their nature and the potential necessity of performance of preparatory works;
      - establish the order of performance of works due to the general organisation of works and contract deadlines;
      - establish the correlations with other components performed on the site (at the facility);
   b) Decide upon the mode of performance of the (complex) process of excavation.
Although the process of excavation, in the simplest case, consists only of two simple processes, that is, loosening of rock and its transport, specific conditions (as listed in letter “a”) may result in the process becoming much more complex (e.g. due to adding the process of ripping of soil, if the works are to be performed in highly cohesive soil). Such complexity may also be associated with the machines used. (in cases where it is necessary to load soil separately to transport vehicles, if loosening rock is performed using bulldozers, and the soil must be transported large distances). It should be noted that such processes in the case of excavations emerge along the main series of processes;

c) Select the sets of machines with regard to their technological properties and capacity and propose the directions of progress of works, as well as diagrams of routes of work of individual types of machines;

d) Set out the excavations and other components as necessary;

e) Gather the machines and their operators as necessary;

f) Commence the implementation of the process.

II. In the case of embankments:

a) Gather preliminary information, that is:
   • define the parameters of the soil to be used for performance of various parts and fragments of the embankment (at least the type and category);
   • classify the embankment type (wide, line-type) and analyse its shape and dimensions;
   • define the soil compaction parameters to be attained while constructing the embankment;
   • specify the place of intake of soil for construction of the embankment (distance from the place of performance of works, types of roads, entry);
   • recognise the possibility of emergence of factors hindering works and their nature and the possible necessity of performance of preparatory works;
   • establish the order of performance of works due to the general organisation of works and contract deadlines;
   • establish the correlations with other components performed on the site (at the facility);

b) Make the decision with regard to performance of the (complex) embankment construction process.
Although the process of embankment construction, in the simplest case, consists only of three simple processes, that is, transport of soil, laying and compacting of soil, the specific conditions (listed in letter “a”) may result in the process becoming much more complex (e.g. the process of transporting water and wetting the soil layers in order to reach its optimum humidity for soil compaction). These changes may also be associated with machines used for the process (If the decision is made to combine the soil laying and transport processes, when the embankment is made using scrapers). It should be noted that when building embankments, such processes may emerge along the main line of processes (watering of soil layers) or as auxiliary processes (transport of water);

c) Select the sets of machines with regard to their technological properties and capacity and propose the directions of progress of works, as well as diagrams of routes of work of individual types of machines;

d) Set out the excavations and other components as necessary;

e) Gather the machines and their operators as necessary;

f) Commence implementation of the process.

4.2.3.3 Preparation of implementation of bricked construction components

In general, the process of performance of bricked structures in its main part is a single-component set containing the simple process of "bricklaying”, which consists of three operations: “establishing the shape and layers of bricked components”, “laying mortar” and “laying bricks”. However, for implementation of the process, the following auxiliary processes are necessary:

• production and delivery of mortar;
• completion and supply of bricks (or other bricklaying components);
• ensuring the appropriate scaffolding, that is, completion and delivery of scaffolding components and their assembly;

The process itself is performed as it has been for centuries, only manually; therefore, the decisive factor for preparation and implementation of the process is specification and selection of the appropriate work teams and providing them with good work conditions. Therefore, in relation to the main "bricklaying” process, it is necessary to:

• decide on the size of basic work teams to perform the process;
• divide the task into working plots (of approximately the same quantity of works), and the plots into individual workstations for work teams,
• establish the height of individual work zones,
• define the number of basic teams included in the gang on the basis of contract deadlines.

With regard to auxiliary processes, it is necessary to:

a) For mortar production and delivery:
• decide on the mode and place of production of mortar, which may include: production at the mortar production plant at the facility constructed (in such case, it is necessary to design such plant or select a typical solution proposed by the appropriate manufacturers of equipment), supplied from a central mortar production plant, prepared at the workstation of bricklayers using factory-made dry mixes;
• specify the appropriate number and type of transport vehicles and work teams;

b) For the brick completion and delivery process:
• check the packages of bricks provided by the selected manufacturer;
• appropriately select the transport vehicles and unloading equipment and the number of work teams necessary;

c) For the scaffolding delivery process:
• select the most appropriate scaffolding;
• design an appropriate set of scaffolding components ensuring efficient flow of works and their movements during subsequent stages of works;
• specify the mode of transport of scaffolding components from the storage yard to bricklayer workstations and upon shifting of workstations;
• specify the composition of the scaffolding handling team,

d) Ensure the physical supply of materials, equipment and teams;

e) Commence the implementation of the process.

4.2.3.4 Preparation of performance of ferroconcrete components

Performance of concrete and ferroconcrete components constitutes a complex construction process, consisting of the following simple processes:
• specifying positioning of construction components;
• installing formwork;
• installing reinforcement;
• filling the formwork with concrete mix and compacting;
• curing concrete mix in the structure;
• form stripping.

For efficient performance of these processes, it is also necessary to implement the following auxiliary processes:

• Preparation and transport of the formwork components;
• Preparation and transport of the reinforcement components;
• Preparation and transport of concrete mix;
• Preparation and transport of components necessary for the appropriate curing of the concrete mix;
• Cleaning and small repairs of the formwork components;
• Coating of formwork components with anti-adhesive agents.

The first tasks to be conducted when preparing construction of ferroconcrete components is division of the structure into plots and defining the work rhythm for these plots, which would ensure compliance with the contract deadlines for the structure built. Division into plots is also associated with the order of measurements and specification of position of individual structural components. The latter is usually performed in Poland by specialist land survey teams.

To commence the complex process of construction of ferroconcrete structures, it is necessary to:

a) In the formwork process:
• select the type of formwork to be used;
• propose the layout of formwork components on the plot;
• decide where the formwork components are to be assembled and how they will be transported to the place of use;
• analyse the correlation between assembly of the formwork and assembly of the reinforcement and make the appropriate decisions;
• specify the required composition of work teams to assemble the formwork;

b) In the reinforcement process:
• decide on the location for preparation of the reinforcement and its form and the mode of delivery to the place of installation and the location of temporary storage yards;
• specify the mode of assembly of reinforcement of individual types of components, taking into account synchronisation of these activities with the formwork processes;
• specify the composition of teams assembling the reinforcement;
c) In the process of laying of concrete mix:
   - decide on the origin of concrete mix (production plant at the facility, central plant on site, commercial manufacturer);
   - specify the mode of transport of concrete mix: from the manufacturer to the site and to the place of use;
   - specify the type and number of transport vehicles needed;
   - specify the appropriate way of laying the concrete mix and its compacting;
   - select the appropriate equipment necessary to lay and compact the concrete mix and its quantity;
   - select the appropriate team of workers;

d) In the process of curing the concrete mix in the structure:
   - specify the method of curing the concrete mix;
   - specify the deadlines for curing activities;
   - select the right equipment for curing and its quantity;
   - specify the person to conduct curing activities and the number of employees needed;

e) In the form stripping process:
   - define the dates and order of form stripping for construction components;
   - define the order and mode of uncovering of individual spaces for each type of construction component;
   - define the place of storage and mode of transport of individual formwork components,
   - select the form stripping team;

f) Physically gather the equipment and concreting gang;

g) Launch the production processes.

4.2.3.5 Preparation of the Processes of Assembly of Structures Made of Ready Components

Preparing the implementation of assembly processes, it is necessary to realise that the issue is to be analysed from the perspective of two aspects, that is, the structure as a whole and individual types of components:

1. Analysing the structure as a whole, it is necessary to:
   a) Examine:
      - the basic structure dimensions;
      - the static diagram;
      - division of structure into components;
      - types of connections between components;
• set of components for assembly;

b) Select the assembly method adequate for the structure type and the assembly conditions, including:
• the type of assembly machine to be used;
• distribution of work stations of the assembly machine or its route (in the case of mobile machines);
• distribution of places of storage of prefab components (their equipment and capacity) or the places of their unloading from transport vehicle;
• type of transport vehicles delivering prefabricated components;
• basic required parameters of assembly machine and its type;
• division of structure into plots;
• general and detailed order of assembly;
• types and number of auxiliary equipment for assembly.

2. Analysing the assembly of individual components, it is necessary to define the mode of:
• storage of the component at the storage yard;
• fixing, lifting, movement to place of assembly;
• positioning at the place of assembly;
• temporary fixing;
• safe disconnecting of lifting slings;
• procedure and order of performance of permanent fixing;
• selection of the assembly team.

3. In relation to the entire structure and individual components, it is necessary to:
• prepare a safe assembly instruction on the basis of legal provisions in force and experience;
• gather the machines, equipment and assembly gang as necessary.
4.3 PREPARATION OF THE CONSTRUCTION SITE

4.3.1 GENERAL CONDITIONS

4.3.1.1 SITE PREPARATION COMPONENTS

A construction site is an area which is organisationally separated from the building ground, managed with regard to its technical and social functions in accordance with the purpose of performance of construction and assembly works within the entire building ground or part of it. The construction site encompasses the building ground in whole or in part and is designated for construction of a single facility or a specific set of facilities or works.

Preparation of the construction site encompasses all activities to be undertaken to organise the construction site so that all processes taking place are provided with all necessary production factors in the required quantity, delivered to the right place and at the right time. The mode of solving of these problems should be indicated in the implementation assumptions, and the details should be provided by contractors for works. The construction site is a separated area, designated for performance of activities associated directly with construction of a given facility or complex of facilities. The size of the construction site is to be determined individually each time, taking into account the local conditions. Assuming no limitations with regard to the available land, the size of the construction site can be presented as the total area occupied by development of the facilities constructed and the area occupied by all elements of land development. The construction site development elements usually include:

- roads within the construction site;
- storage yards (open and roofed) and closed warehouses;
- production equipment (e.g. concrete mixing plants, steel yards, carpenter shops);
- general equipment and installations, that is, water, power, heat supply, compressed air supply systems etc.;
- administrative buildings, amenity buildings and sanitary facilities;
- fences, information boards and security guard facilities.

Proportions between individual areas vary and depend upon the nature of the construction site, local conditions and the implementation methodology.
Development of the construction site may change during subsequent stages of implementation of the construction project; in such case, development plans should be prepared for each of these stages.

In some cases, the construction site area is not much greater than the development area. Such a situation is very inconvenient from the perspective of completion of works; it is usually encountered during construction projects implemented in large cities. Under such circumstances, the basic task is to ensure regular delivery of materials and products, sometimes in accordance with precise time schedules. This may lead to great organisational problems. An opposite case is conducting construction tasks on a site which is too large. Such a situation is also disadvantageous as it leads to excessive scattering of equipment on the site and longer transport routes.

4.3.1.2 PREPARATION OF THE CONSTRUCTION SITE IN SPECIFIC CONDITIONS

The servant nature of the construction site development requires in the first place determination of the conditions to be met. These conditions can be:

a) of formal and legal nature, resulting from the legal system applicable within the construction area which must be complied with in terms of development of the construction site;

b) of technical nature, resulting from the characteristics and scale of the undertaking;

c) of technological nature, specifying the sets of activities associated with implementation of individual processes, which result, among other things, in determining the application of specific production devices, the degree of mechanization of processes, requirements with regard to qualifications of employees hired and the sizes of basic work teams;

d) of organisational nature, associated with the adapted organisation of implementation of the undertaking, usually recorded in the schedules. Ordinary schedules serve as a basis for determination of the following:

- the order of completion of individual construction processes;
- the timing of these processes and the daily performance values;

The schedules define the stages for implementing the undertaking and the resulting deadlines for implementation of individual processes, as well as the means of production necessary during subsequent periods.

This allows for determination of: schedules of preparation of individual elements of development of the construction site, as well as the demand for power, steam,
compressed air and water, which serves as a basis for designing the temporary construction site facilities.

On the basis of material demand schedules, the applicable area of storage yards and warehouses is determined. The employment schedules serve as a basis for specification of the dimensions of temporary administrative and amenity buildings, while the machine operation schedules allow for specification of their number, work schedules, time periods of their use on the construction site, as well as the necessary access routes, vehicle manoeuvre areas and parking places.

4.3.1.3 THE ORDER OF DESIGNING OF THE CONSTRUCTION SITE DEVELOPMENT

A good site development design can be prepared only thanks to good familiarity with local conditions. This requires analysis of local conditions for the undertaking planned. To conduct the site topography study, we usually use a topographic map of scale 1:25000 with contour lines every 5m or a map of scale 1:100000. The map section should encompass the construction area, allowing for determination of the location of the following components:

- marks of the state geodetic network, located nearest to the construction site;
- roads connecting the construction site with production plants, storage areas, railway stations etc;
- rail roads;
- construction material mines;
- power intake points;
- elevation marks of natural and artificial water reservoirs.

It should always be kept in mind that the basic factors which shape the size of the construction area for the purpose of design are:

- location of the unloading railway station in relation to the site or the possibility of construction of unloading sidings and ramps at the nearest railway post;
- location of aggregate, stone mines etc.;
- water intake sources;
- manufacturing plants and storage yards of materials;
- sources of power supply.

Location of these components in relation to the construction site determines the range of the construction site and specifies the technical and economic conditions.
of the construction site, which are then reflected in the costs of developing the construction site. The scope of determination of the local condition depends on the size and type of construction (e.g. construction in a city or in rural areas).

When designing the construction site development it is necessary to follow the appropriate order of distribution of its components. The recommended order is as follows:

1. Roads on the construction site, providing access to the site from the nearest railway station, highway or other road;
2. Storage yards of materials and construction components and warehouses with loading/unloading equipment;
3. Equipment for production of semi-finished products (e.g. concrete-mixing plants, steel yards, carpenter shops), devices for production of semi-finished products (concrete, ferroconcrete, metal), servicing equipment (construction machine park, transport base, material base);
4. Administrative buildings, amenity and sanitary buildings (temporary) on site for workers and technical personnel employed on the site (the rest and refreshment areas);
5. General equipment and systems, providing power and water supply, compressed air, steam, fire protection equipment etc.

**4.3.1.4 THE ORDER OF IMPLEMENTATION OF THE CONSTRUCTION SITE DEVELOPMENT TASKS**

The order of implementation of the construction site components usually differs from the order applied during design, and it is usually as follows:

1. Establishment of the boundaries of the land plot (construction site);
2. Fencing and securing the construction site and information boards;
3. Premises for the construction management and temporary warehouses, constructed simultaneously with rest and refreshment areas for employees;
4. Construction of traffic routes, commenced by construction of an access route, while the construction of internal routes should be divided into stages in accordance with construction of facilities listed in clause 3;
5. Construction of individual manufacturing and service facilities takes place in accordance with the general construction schedules for commencement of individual construction works. Usually, the order of construction of the production facilities is as follows:
   - warehouses;
   - workshops;
   - transport bases;
   - subcontractor bases.
Construction of the rest and refreshment areas and production facilities requires supply of water, power, heat etc. This enforces the appropriate division of implementation of individual utility networks into stages.

At many construction sites it is possible to use some of the permanent facilities, included in the design, for the purposes of development of the construction site. Construction of these facilities should be commenced first, which should be indicated in the investment project implementation schedule; this reduces the costs of development of the construction site.

The cost of development of the construction site is within $2 \div 7\%$ of the value of facilities constructed.

As for any design, it is necessary to prepare several versions of development of the construction site, and the decision concerning the version subject to implementation should be made only on the basis of optimisation calculations.

### 4.3.2 The principles of designing of the basic site development components

#### 4.3.2.1 The construction site roads

When designing the network of roads within the construction site it is necessary to take into account: the existing public road network; access roads connecting the construction area with the public road network; internal roads on the construction site.

Designing roads on the construction site is based on determination of the following components:

- the flow diagram of loads;
- establishing routes for external transport vehicles along the internal construction site roads;
- the appropriate unloading sites;
- the appropriate road subsoil and pavement characteristics;
- the appropriate road parameters (width, turn radius, inclination, appropriate subsoil and pavement);
- the appropriate methods of loading and unloading.
The following factors influence the construction of temporary roads on site:

- road load, or the mass of load transported per unit of time;
- type of transport vehicles and their velocity;
- the planned time of operation of the road;
- geological and hydrological site conditions;
- availability of road construction materials.

The layout of internal site roads should ensure:

- access of transport vehicles close to their destination;
- roads for delivery of materials being located within the range of operation of lifting equipment (if such equipment is used);
- in the case of a road running along the facility under construction, sufficient space is to be left between the facility and the road to store materials and construction products and to conduct auxiliary works;
- a safe distance is maintained between the road and the medium and high voltage overhead lines above the construction site and the machines, scaffolds, auxiliary buildings and excavations.

Temporary roads on the site are designed as one-way or two-way roads, meeting the following requirements:

- the width of a one-way road should be 3.0÷4.0m, and the width of two-way roads should be 6.0÷8.0m. Road widening near the unloading yards should be at least to 3.5m;
- longitudinal road inclination should not exceed 6%. Longitudinal inclinations for discharge of rainwater: 0.2 ÷1.0%;
- perpendicular roadway inclination 2.0÷3.0%, for shoulders - 5%;
- the curve radius of internal construction site roads should be at least 20.0m. Along the curve, the roadway should be widened on the inside; the scope of such widening depends on vehicle length and the turning radius; such widening, appropriate for these parameters, is to be read from tables provided in various manuals and it ranges from 1.8 to 2.2m.

The following road layouts are applicable to construction sites:

- with a separate entrance and exit from the site;
- with a shared entrance and exit from the site.

Roads with shared entrances and exits from the site are usually in accordance with the following layouts:

- alternating traffic, used at small construction sites, where road traffic usually takes place along a single axis;
- radiant, applicable to medium-sized construction sites, where vehicle traffic takes place along several axes which are brought together at the entrance to the site;
- circumferential, applicable to large construction sites, developed irregularly, where vehicle traffic takes place along a closed route, passing along all unloading points.

An advantage of alternating and radiant traffic is that the roads are relatively short in comparison with the circumferential layout. A disadvantage is the necessity of turning the transport vehicles. To ensure the possibility of this manoeuvre, at the end of each road branch, it is necessary to provide a turning circle, which is a circular fragment of the road or a turning slab, which is a trapezoid-shaped widening of the final section of the road.

The (internal) diameter of the turning circle depends on the structure of the transport vehicle and its load-bearing capacity. This value is based on tables specifying these parameters. It ranges from 14.0 to 24.0m. The road width within the turning circle should not be less than 6.0m.

Turning slabs are in the shape of a trapezoid and they require less space than the turning circle. However, they make the turning manoeuvre more difficult. The approximate dimensions of the turning slab are 14.0-18.0m height of the trapezoid (perpendicular to the road axis), smaller base 8.0-10.0m (parallel to the road axis), larger base 14.0-18.0m.

The road layout with a separate entrance and exit provides better traffic solutions in comparison with a shared entrance and exit layout. Two solutions are applied:
- pass-through layout, which reduces the possibility of collision during traffic and usually does not require roads of substantial length; however, it requires a double link to the public road system;
- a closed perimeter layout, which allows for organisation of traffic with separate directions at the site, but requires roads of substantial length and a double link to the public road system.

Temporary roads on site may be constructed as follows:
- as dirt roads, used for small traffic intensity and application of light transport vehicles. These include:
  - natural dirt roads, or separated routes, which can be profiled and compacted using road rollers with loads of 30÷60 kN; they can be used for traffic of intensity not exceeding 5000 kN/day;
• improved dirt roads, with enforced traffic lanes, e.g. through mechanical stabilisation of the soil, adding setting materials (cement, lime, asphalt), improvement of the soil grain size parameters and mechanical compacting. The traffic intensity along an improved dirt road may reach about 8000 kN/day;
• as gravel roads (sometimes also made of rubble or slag), constructed directly on the soil, if the soil is permeable, or on a layer of sand, if the soil is not permeable. Such roads are constructed by laying and rolling a layer of gravel, sometimes adding clay as an adhesive material. The thickness of the sand and gravel layer laid and thickened should be about 30 cm. Traffic intensity should not exceed 1000 kN/day;
• as paved roads made of field stone, highly resistant to all kinds of construction transport vehicles. Construction of such a road requires hard work. It is laid manually on a layer of sand which is placed in a road bed made in the soil; therefore, they are now used very rarely;
• as roads made of concrete and ferroconcrete prefabricates. The following are applied:
  o rectangular ferroconcrete full slabs (e.g. MON type of dimensions 100x300x20cm and a mass of 1.5t). They may be laid perpendicular to the road axis. This result in a fully developed surface. If laid along the road surface, only strips under the wheels of vehicles are obtained. When the latter mode of construction is used, the entire roadway surface is to be covered at the curves.
  o trapezoid-shaped ferroconcrete slabs, ribbed (e.g. type CBSTDIL of dimensions of 102/118x300x14), laid in a similar manner as the MON slabs, provided that along straight sections they are laid alternately along their shorter and longer side, and along curves, the subsequent slabs are laid so that the sides of the same length are adjacent to each other.
  o rectangular ferroconcrete multi-hole slabs (e.g. of type IOMB, which are produced in two sizes: for manual laying of dimensions of 100x75x12.5 cm and a mass of 177kg and for mechanical laying of dimensions of 100x175x15cm and a mass of 500kg) which are laid to establish two traffic lanes under the vehicle wheels. Slabs are laid along the entire road surface only along the turn-outs and curves;
  o hexagonal concrete slabs (e.g. type DT, of diagonal of the length of 100cm and thickness of 17cm); like the former, they can be laid across the entire road surface or to form two traffic lanes.

Roads made of concrete and ferroconcrete prefabricates are used most often. It is now believed that for vehicles of load-carrying capacity above 6t, roads should be
constructed of concrete and ferroconcrete prefabricates. Such roads can be laid directly on sandy soils or on a layer of sand on soils of medium permeability.

Low permeability soils require a subsoil of breakstone or coarse grain gravel.

4.3.2.2 STORAGE YARDS AND WAREHOUSES

Depending on the scope of the undertaking, the assumed concept of organisation and the conditions of the construction site, it is necessary to provide space for storage of materials, products and prefabricated components prior to their use. It is also necessary to ensure the appropriate equipment for storage of construction equipment, when it is not used at the workstations. The conditions of proper storage of these resources should be ensured by the appropriate storage system on the site. The methods of transporting and storing materials and products are specified in the applicable standards and documents that authorise the general use of products. The storage system includes storage yards and warehouses. These facilities can be open, roofed or closed.

Storage yards – the storage yards should be levelled and drained. The storage yard pavement consists of the same materials as the temporary roads on the site.

Umbrella roofs can be made of wood or reusable metal. They are used for storage of materials sensitive to rainfall.

Closed warehouses are used to store construction materials sensitive to weather conditions, as well as tools, parts of machines, electronic devices, sanitary materials, fixtures etc. Warehouses should be provided with partitions, stands, shelves, ladders and light equipment for local transport.

Closed warehouses and umbrella roofs should be located near the management building, which facilitates supervision of materials.

Storage yards of bulk and heavy materials are to be placed along the roads, as close as possible to the facilities under construction. Materials for production of prefabricated products, such as aggregate, cement, reinforcement steel, sawn timber should be placed near the location of production of concrete mix, mortar, reinforcements, formwork etc.

The structure of temporary warehouse buildings must allow for their easy assembly, disassembly and transport. At present, prefabricated temporary facilities are available. They are designed mainly on the basis of steel structures. There are
two main types of these: buildings made of flat prefabricated components and buildings made of three-dimensional components, the so-called containers. Companies producing such buildings offer ready solutions of individual building types and catalogues, which allow for factory assembly of components.

Calculating the area of storage yards and warehouses, we distinguish the usable (net) space occupied directly by materials, and general (gross) space, which includes the necessary passages and access routes. The net space is calculated on the basis of the following formula:

\[ F = \frac{Z}{q} \]  \hspace{1cm} (4.1)

Where: \( Z \) – is the reserve of stored materials in physical units: t, pc, etc. (usually obtained from schedules of consumption and reserves of materials),

\( q \) – the quantity of materials per 1m\(^2\) of the storage yard area (the so-called storage index) m\(^2\), m\(^3\), or t.

Gross space is calculated according to formula:

\[ F_b = F k_{mag} \]  \hspace{1cm} (4.2)

Where: \( k_{mag} \) is the coefficient of use of the storage area (warehouse) space, or ratio of \( F_b \) to \( F \) for individual materials. The values of \( k_{mag} \) and \( q \) are normative. These can be found in various manuals. The \( k_{mag} \) coefficient may assume a quite broad range of values, from 1.2 for bulk materials to more than 2.5, e.g. for reinforcement steel.

In the case of equivalent storage of various materials within the same storage space, this area is calculated according to the following formulas:

\[ F_n = \sum_{i=1}^{n} \frac{Z_i}{q_i} \]  \hspace{1cm} (4.3)

\[ F_b = \sum_{i=1}^{n} \frac{Z_i}{q_i} k_{magi} \]  \hspace{1cm} (4.4)
Where: \( n \) – is the quantity of materials stored.

To ensure the proper operation of the storage yard, it is also necessary to determine the minimum required length of the loading/unloading field and ensure its optimum depth.

The length of the loading/unloading field is the minimum length of the storage yard necessary for loading or unloading of simultaneously arriving transport vehicles. This value can be established in a deterministic or probabilistic manner using the mass handling theory.

The length of the loading/unloading field is established in a deterministic manner according to formula:

\[
L = \frac{Q w_1 l w_2}{q_t n}, \text{ [m]} \tag{4.5}
\]

Where: 
- \( Q \) – is the quantity of material supplied to the construction site per day in t, m\(^2\) or pieces (according to the material delivery schedule), 
- \( q_t \) – is the load-carrying capacity of the transport vehicle per day in t, m\(^2\) or pieces, 
- \( n \) - the number of work cycles of transport vehicles per day, 
- \( l \) - the length of the unloading field of the transport vehicle in m (which is based on the structural dimensions of the vehicle), 
- \( w_1 \) – is the coefficient of irregularity of delivery, which is assumed to be: in the case of delivery by railway to a siding on the site 1.3 ÷ 1.8; by trucks – 1.3 ÷ 1.5, 
- \( w_2 \) – the increase coefficient, introduced to take into account the necessary intervals between vehicles; the values of \( w_2 \) are assumed as follows:
  - for truck and tractor transport 1.2 ÷ 1.5, 
  - for railway wagons 1.2 ÷ 1.3.

The mode of calculation of the loading/unloading field length using the mass handling theory can be found in operating research textbooks, referring to construction trade.
4.3.2.3 ADMINISTRATIVE, AMENITY AND SANITARY BUILDINGS

Administrative buildings are usually located near the main entrance to the site. They usually include the construction management building and facilities for administrative personnel of the construction site.

Amenity and sanitary buildings include: changing rooms, washrooms, toilets, kitchens, cafeterias, recreation rooms and first aid rooms, and sometimes accommodation space. The size of these buildings depends on the number of employees on the site. The building area necessary to ensure rendering of appropriate services is calculated on the basis of the applicable coefficients. In general, it is assumed that an increase in the number of employees results in reduction of the indicators of necessary space per blue or white collar worker; however, these values cannot be lesser than specified in the applicable legal provisions. Designing the administrative and amenity buildings using the tables and coefficients provided in textbooks and manuals, it is always necessary to make sure that the areas obtained are compliant with the requirements of the valid legal provisions. As in the case of determination of the area of storage space, the values obtained are to be increased to include the necessary traffic routes. The area for traffic in administrative and amenity buildings is about 13%, and the area occupied by structures is equivalent to 7% of general area.

As for their structure, administrative and amenity buildings should usually be typical, allowing for their disassembly and transport. These can be:

- facilities allowing for their disassembly, made of proprietary flat components;
- allowing for transport on their own running gear (the so-called construction site trailers) and transported on carriages;
- of container type, made of three-dimensional components, which are transported on special running gear;
- semi-permanent, constructed in a traditional manner, which should be avoided for economical reasons, and applied mainly on construction sites, where the implementation period is long.

Components used for construction of administrative and amenity buildings are usually made of wood, metal or plastics. They should be light, allow for easy assembly and disassembly and transport.

Numerous additional requirements are usually provided for administrative and amenity buildings. For instance, in Poland, on a construction site where the construction period does not exceed one year, it is necessary to provide separate
spaces for employees as cafeterias, changing rooms, as well as a room for making beverages, drying clothes, washrooms and toilets.

At construction sites designated for many years, it is necessary to provide the employees with changing rooms for dirty and clean clothes, cafeterias, a room for drying clothes, washrooms, showers, a room for making beverages, personal hygiene cabins for women and toilets.

The usable space of the clean clothes changing room should be 0.65m$^2$, and the dirty clothes changing room 0.5m$^2$ per employee. The clean and dirty clothes changing rooms should be located in separate rooms. The changing room is to be equipped with ventilated lockers and stools in the number equivalent to the number of employees. The distance between the changing room and the workstation should not exceed 500m.

The area of the cafeteria cannot be less than 0.7m$^2$ per employee, taking into account the most numerous shift. The cafeteria room should be equipped with tables and stools. The distance between the cafeteria and the workstation should not exceed 200m. If the cafeteria is not located next to the washroom, it is necessary to provide a hand washing facility (1 valve per 20 persons).

In the drying room, at least 0.4m$^2$ of space should be designated per employee, taking into account the most numerous shift. The drying room should be located next to the changing room.

Changing rooms should be directly connected with washrooms, in which one washing facility should be provided per 7 employees, taking into account the most numerous shift. Hot water should be supplied for at least 60% of all basins installed.

If more than five women are employed on the site, it is necessary to provide them with a personal hygiene cabin of at least 1.5m$^2$, equipped with a bidet and a basin with hot and cold water. One cabin should be provided for no more than 200 women.

The toilet should be equipped with at least one toilet seat per 25 employees. At present, toilet cabins are used which are delivered, emptied and disinfected by specialist companies. This allows for placing them near the workstation and ensures environmental protection.
The construction site should also be equipped with a first aid room. On sites employing up to 150 employees, the first aid room should be located in the administrative building of the construction site management. It is served by one of the white collar workers who has completed first aid training. On large construction sites, the first aid room is located in the amenity building. In such cases it is necessary to hire an employee with secondary medical education to serve the first aid room.

4.3.2.4 General Use Equipment on the Site

General use equipment on site includes the technical components to supply the construction site with water, power, heat, compressed air etc. Water and power supply installations are always present on the site; these will be discussed later in this manual. Other systems are encountered rarely, and information concerning these can be obtained from specialist literature on the subject.

Water supply on the construction site:

Water on site can be used for production purposes (e.g. water for production of concrete mix, concrete curing etc.), for utility purposes (cooking, sanitary purposes etc.), for fire protection (water used to extinguish fires). Depending on the scope of consumption of water on the site, it can be referred to as low or high.

Small construction sites, characterised by low water consumption, meet the requirements of the inequality:

\[ q_p + q_g < q_{pp} \]  \hspace{1cm} (4.6)

Where:
- \( q_p \) – construction site water demand for production [l/s],
- \( q_g \) – construction site water demand for utility purposes [l/s],
- \( q_{pp} \) – construction site water demand for fire protection [l/s].

In the case of small construction sites, general water consumption is calculated according to formula:

\[ Q = q_{pp}, \quad [l/s] \]  \hspace{1cm} (4.7)
Large construction sites, characterised by high water consumption, meet the conditions of inequality:

\[ q_p + q_s > q_{pp} \]  

(4.8)

in the case of large construction sites, general water consumption is determined according to formula:

\[ Q_{pp} = q_{pp} + \frac{1}{2} (q_p + q_s), \ [l/s] \]  

(4.9)

Consumption of water for production purposes is calculated according to formula:

\[ q_p = 1,2 \left(\frac{k}{8 \times 3600}\right) \sum R_b, \ [l/s] \]  

(4.10)

where: \( k \) - is the coefficient of irregularity of consumption.

\( \sum R_b \) - the total demand for water for individual types of works:

This total is obtained by adding products of daily production to water consumption indicators. It is possible to refer to column 10 of the analytical part of the general construction schedule,

1,2 - the coefficient of increase, taking into account the water consumption for production, not taken into account in the tables.

Water consumption for utility purposes is calculated on the basis of formula:

\[ q_s = q_{gb} + q_{gh}, \ [l/s] \]  

(4.11)

Where: \( q_{gb} \) - water consumption on site,

\( q_{gh} \) - water consumption at the accommodation facilities.

These components are calculated according to formulas:

\[ q_{gb} = 2,7 \left(\frac{10N + \sum p}{8 \times 3600}\right), \ [l/s] \]  

(4.12)
\[ q_{qh} = 2.0 \frac{25N' + \sum p'}{24 \times 3600}, \text{ [l/s]} \quad (4.13) \]

Where: 2.7 and 2.0 are the coefficients of irregularity of consumption,
\( N \) - number of site employees,
\( N' \) – number of employees taking advantage of accommodation facilities,
\( \sum p' \) – total water consumption for sanitary and utility purposes is established according to the consumption table. The value of consumption of water for fire protection is to be determined in consultation with the local fire services. As an estimate, it is assumed to be:
- for construction sites of area up to 30 ha 10l/s,
- for each subsequent 50 ha of area 5l/s,
- for separate accommodation facilities 5l/s.

The diameter of water supply pipes is calculated according to formula:
\[ d = \sqrt{\frac{4Q}{\pi v_w}}, \text{ [m]} \quad (4.14) \]

Where: \( Q \) – the general water consumption, established as discussed above,
\( v_w \) – the water flow rate assumed to be within 1.0÷1.5m/s.

The water supply network on site can be designed as:
- one-way, where individual water intakes are connected to a single main line, supplied at one point;
- circumferential, where individual water intakes are connected to a single main line in form of a perimeter, supplied at more than one point.

One-way pipelines are used at small construction sites or elongated construction sites. A disadvantage of these networks is discontinuation of water supply at water intakes behind the place of defect. However, such networks are relatively cheap. Circumferential networks are used at larger construction sites. They are highly reliable, as in the case of a failure of the water supply system on one side, they can be supplied on the other side. Mixed networks, consisting of components of both of these solutions, can also be applied.

Water pipelines are laid in the ground at the depth of 1.0÷1.4m, usually along the construction site roads at a distance of about 1.0m from their edge.
In order to ensure fire protection of the site, the water supply network must be equipped with hydrants. The distance between hydrants should not exceed 80m, and the distance between hydrants and the facilities or temporary buildings cannot be less than 10m and more than 25m.

Power supply for the construction site:

Power consumed at the site is used for three basic purposes: as energy to supply machines and equipment, as energy used for internal lighting of the construction site development components and external lighting of the construction site, and energy used for heating purposes.

The construction site may be supplied with power from:

- The municipal grid, which provides energy of utilisation voltage, if the transformer station of the local grid has the appropriate power reserve;
- A high voltage power network, from which energy is transformed using a transformer installed on the site;
- Own power generation unit, usually of 50 ÷ 100 kW, if the site is located at a substantial distance from the power supply network and thus supplying power from the grid is not economical.

The apparent transformer or generator power, necessary for the construction site, is determined on the basis of formula:

$$P_{poz} = 1,1 \left( \frac{K_s \sum P_s}{\cos \varphi} + K_{ow} \sum P_{ow} + K_{oz} \sum P_{oz} \right) \text{[kVA]}$$ (4.15)

Where:

- $\cos \varphi$ - the power coefficient read from the table according to the general forecast power demand and the number of working shifts on the site,
- $K_s$ - coefficient of simultaneous operation of engines,
- $K_{ow}$ - coefficient of simultaneous operation of interior lighting,
- $K_{oz}$ - coefficient of simultaneous operation of exterior lighting,
- $\sum P_s$ - total power of engines of machines installed on the site in KW,
- $\sum P_{oz}$ – total power of lighting sources on the site outside buildings in KW.

The values of coefficients of simultaneous power consumption by operating electric engines are read from tables according to machine type and quantity. It can be approximately assumed that the coefficient of simultaneous power consumption
for two engines is 0.75; for three to five engines 0.60; and above five engines - 0.50. The power of engines in individual types of machines is obtained from their rating plates.

The average demand for power for external and internal lighting is read from tables, where it is provided in W/100m², for external lighting – depending on the type of works or the area occupied, and for internal lighting – depending on the sub-type of facilities.

If electric heating is used on the site, the power calculated $P_{poz}$ is to be increased by quotient $\frac{\sum P_s}{\cos \varphi}$, $\frac{\sum P_s}{\cos \varphi}$

Where: $P_e$ – demand for nominal power used for heating.

The demand for electric energy, calculated in this way, is applicable to small construction sites (category I, power demand up to 25KW) and medium-sized sites (category II power demand 25-100KW), as well as medium sized sites (category I and II). For large sites (category III, up to 500KW and IV, above 500KW), it is necessary to prepare daily charts of power demand, which serve as a basis for determination of the power demand.

A transformer on the site should be as close as possible to the most central location in relation to the power intake points. It is assumed that the most advantageous radius of operation of transformers that reduce voltage to 380/220 V is 300÷400m, while the maximum allowable radius is 700m. The power supply network of the construction site consists of main lines and side distribution lines, as well as the power and lighting branch lines. Large construction sites should have separate circuits for power and lighting. The conductors should be suspended on common supports, and cables should be laid in common excavations.

Overhead lines can only be used in those parts of the construction sites which are beyond the range of operation of machines with extension arms. In other locations, power is to be distributed using cables. Cable cores should be indicated in the field e.g. by red flags, so that they are not damaged during earthworks. Non-insulated electric conductors must be placed at a height of more than 5m above the ground and at least 3m above the scaffoldings, platforms and other employee workstations.

Power supply networks on the site should be designed and performed by qualified electricity engineers.
Other site development components are: fences, production equipment, communication systems.

Construction site fences are now made of proprietary components. In most cases, they are made of metal, in form of frames made of angle bars filled with trapezoid metal sheets, metal mesh or, less often, wood derivatives. Such fencing slabs are attached to steel posts, spaced in accordance with slab sizes, within 2.0÷3.0m. The posts are sunk into the ground or fixed to special concrete blocks, placed directly on the ground (the latter solution is usually applied in large cities, where the fencing runs along paved area, e.g. a road or a sidewalk). The second type of universally used fencing is a fence made of trapezoid metal sheets fixed directly to metal posts. The spacing between posts in such case depends on the length of metal sheets applied. According to legal provisions applicable in Poland, the fence height cannot be less than 150cm. It is usually 180cm high.

Usually, there is no production equipment on small and medium-sized sites due to dynamic development of various services, such as delivery of concrete mixes, ready reinforcement structures etc. Distribution and design of production equipment on sites is a problem which emerges on large sites, particularly in non-industrialised areas. These issues are solved using one of the methods of optimisation, belonging to the field of operational research.

The communication network on sites, particularly the small ones, is no longer a problem thanks to universal use of mobile phones.

4.4 OCCUPATIONAL HEALTH AND SAFETY

4.4.1 INTRODUCTION

The objective of "continuous improvement of the conditions of life and work"\textsuperscript{102} was specified already in the Treaties of Rome (signed on March 25th, 1957),

\textsuperscript{102} Treaty establishing the European Economic Community EEC, part one, Preamble
establishing the European Economic Community. Within the framework of development of this principle, work protection has become a main component of the labour and social policy.  

The objectives of the European labour protection policy are based on the treaty establishing the European Community, in particular, in § 137 item 1 in association with article 95 (nb the numbering of pages of the Treaty establishing the European Community changes along with introduction of the treaty of Lisbon).

Within the framework of labour protection, work conditions are to be adapted to human needs.

The basic rules of organisation of occupational health and safety include:  

- OHS being included in the planning processes;  
- Threats are to be avoided or maintained on a level as low as possible;  
- Threats are to be eliminated at their source;  
- Collective means of protection should have priority in relation to personal means of protection;  
- It is necessary to take into account the technical, organisational, social, environmental and human aspects;  
- In all means of protection, it is necessary to take into account the achievements of labour science and technical knowledge;  
- It is necessary to check and continuously improve the effectiveness of the means of labour protection;  
- Both parties (the employer and the employee) must be informed of the principles of workplace safety and mutually committed to compliance with the provisions in force.

OHS is based on Directive 89/391/EEC on the introduction of measures to encourage improvements in the safety and health of workers at work. The directive is applicable to all private and public areas of activity, except for special activities, specified in public services or civil defense services. It defines the obligations of the employer and the employee.

The employer is obliged to provide the employees with safe and hygienic work conditions, that is:

- Organise work so that safety and health protection are ensured;

---

103 Pieper (2009)  
104 Rundnagel
• Ensure compliance with the orders, regulations and decisions of work condition supervision bodies, such as the State Labour Inspection, the State Sanitary Inspection, the Office for Technical Supervision, the State Fire Service etc;
• Assess and document threats associated with performance of works, e.g. with regard to selection of means of work and organisation of workplaces and involve the services equipped with means of protection and prevention of threats;
• Maintain a list of accidents at work and prepare reports on such accidents;
• Engage in activities required to provide first aid, fire extinguishing and evacuation of employees, or applicable in the case of a serious direct threat;
• Instruct employees, listen to them and enable them to obtain answers to any questions or doubts with regard to proper compliance with the principles of safety and health protection at work;
• Make sure that all employees have undergone proper and sufficient training on safety and health protection.

The employee is obliged to:
• Use (apply) tools, machines and other means of production and personal means of protection and protective devices in a proper manner,
• Report any serious and direct threat and any defect of the protection systems,
• Contribute to compliance with the legal provisions on occupational health and safety, enabling the employer to provide all employees with a safe, threat-free environment and work conditions.  

Compliance with the minimum applicable requirements with regard to safety and health protection for temporary or mobile construction sites is defined in directive 92/57/EEC. It serves as a basis for organisation of construction sites and in many regions it has substantially changed the traditional ways of implementing construction projects. The Council directive 92/57/EEC has been introduced in the Polish legislation through the act on amendment of the Building Law Act and amendment of some legal acts of 27 July 2001 (Journal of Laws of 2001 no. 129, item 1439).  

105  www.europa.eu  
106  Murator
a building permit, when the construction design is being prepared and later, during its implementation. The act has been complemented by the Regulation of the Minister of Infrastructure of 23 June 2003 on information concerning health protection and safety and a health protection and safety plan (Journal of Laws of 2003 no. 120, item 1126). According to these legal provisions:

- The investor is obliged to organise the construction process, taking into account the principles of the provisions on health protection and safety;
- The designer should include in the building permit design the information and conditions on health protection and safety in accordance with the specific nature and characteristics of the construction facility to be built, which are to be taken into account in the health protection and safety plan, and pay particular attention to compliance with these during the project architect’s supervision;
- The construction manager is at the same time a coordinator for health protection and safety on site. Their basic scope of duties includes coordinating implementation of tasks to prevent threats to safety and health protection, taking into account the specific nature of the construction facility and the conditions of performance of construction works, including planning of construction works and industrial production;
- The investor supervision inspector has been obliged to control and report to the investor regularly on the condition of safety and health protection on the site.

According to the legal act, the following construction and assembly works are considered to be dangerous:

- Works which, due to their nature, organisation or place of performance create a particularly high risk of emergence of a threat to human life and health, in particular, a threat of collapse of earth or a fall from height;
- Works which are associated with impact of chemical substances or biological factors that pose a harm to human life and health;
- Works posing a threat of ionising radiation, conducted near high voltage power lines or operational communication lines;
- Works posing a threat of drowning;
- Works conducted in wells, underground and in tunnels;
- Works performed by drivers of vehicles supplied by overhead lines;
- Works performed in caissons with atmosphere generated by compressed air, requiring use of explosives;

---

107 Murator
108 Murator

112
• Works associated with assembly and disassembly of heavy prefabricated components.

Chapter 4.4.2 presents examples of documents associated with occupational health and safety on the construction site, prepared on the basis of the publication of Güteschutzverband Betonschalungen GSV\textsuperscript{109} (Association for Protection of Quality of Concrete Formwork). Chapter 4.4.3, based on the same source documents, presents an example procedure for assessment of threats at work. This document serves as a specific model which can be applied in Germany in accordance with the legal provisions in force.

4.4.2 SELECTED COMPONENTS OF THE CONSTRUCTION DOCUMENTATION PERTAINING TO OHS

A construction site, as a place which generates threats for employees, should be planned and documented in accordance with the requirements of occupational health and safety. Listed below are examples of documents, referring only to documentation of the enterprise which performs works, which, according to the recommendation of GSV, should be present on any construction site, where boarding works are performed (individual conditions should always be taken into account):

• Occupational risk assessment as a document subject to constant supervision (State Labour Inspection and State Health Institute) and updating (see Chapter 4.4.3). The employer is obliged to ensure updating of this document;

• OHS instructions for assembly of formwork. The assembly instruction for formwork includes:
  o the order and type of assembly; if necessary – sub-assembly and disassembly of individual parts;
  o statics of scaffolds and formworks, including during assembly and temporary storage;
  o acceptable concreting speed (fresh concrete pressure);
  o specification of the deadline and duration of formwork removal;
  o description of the workplace, access and protection against fall;
  o protection against falling objects;

\textsuperscript{109} GSV (2007)
o order of placement, relocation and disassembly of the assembled formwork and scaffolding components;
o load-bearing capacity of lifts;
o lifting slings;
o transport (using a truck, a hoist);
o weight of the lifted formwork components;
o points for attachment of the formwork components to the transport device;
o type, number and location of supports and bracings and their fixing;
o weight, location and fixing of the incorporated parts;
o assembly of the reinforcement, laying of concrete mix and other parts of the structure;
o use of personal lifts or baskets;
o other individual documents.

- Other OHS instructions;
- Employee training documentation;
- Instructions for assembly and use of formwork, issued by the manufacturer.
Formwork constitutes technical means of production; which should be used only by qualified employees and properly trained supervision personnel;
- Material control documentation;
Formwork and scaffolding should be controlled at the time of delivery on the site and prior to each use, from the perspective of their proper structure and functioning. No changes in the material characteristics are acceptable.

It is necessary to follow the applicable domestic legal provisions, standards and other OHS provisions. Chapter 4.4.3 presents an example of a procedure for risk assessment of boarding works.

### 4.4.3 OCCUPATIONAL RISK ASSESSMENT METHODOLOGY FOR BOARDING WORKS

In general, it is necessary to comply with the applicable methods of occupational risk assessment for implementation of a construction undertaking, which are binding on national level.

As a rule, the following principle applies:
The employer is responsible for preparation of the occupational risk assessment and effective implementation of the associated means. The construction
management (the construction manager and foremen) are usually charged with responsibility. All employees are obliged to follow the employer’s instructions (if these are correct) and the applicable OHS provisions and to report any objections if the conditions of work are improper.

Assessment of occupational risk should be prepared in a timely manner, prior to commencement of works on site.

The occupational risk documentation is to be maintained on the site.

The content of the occupational risk assessment includes all components that may lead to accidents or injuries.

The example presented below illustrates preparation of the occupational risk assessment for boarding works conducted using frame wall formwork. The procedure consists of five stages.

Stage 1: Specification of the scope of works.

Here: Boarding works using frame wall formwork.

Figure 4.6: Frame wall formwork – placement of formwork component using a crane\(^\text{110}\)

Stage 2: Specification of threats (separation of the work system, specification of threats or dangerous factors for each task)

\(^{110}\) GSV (2007)
A review of threats and dangerous factors can be found in table 4.1.\(^{111}\)

<table>
<thead>
<tr>
<th>Threats or dangerous factors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>lighting</strong></td>
<td>biological materials</td>
</tr>
<tr>
<td>electric shock threat</td>
<td>light and color</td>
</tr>
<tr>
<td>weather</td>
<td>mechanical factors</td>
</tr>
<tr>
<td>physical conditions</td>
<td>psychical factors</td>
</tr>
<tr>
<td>mechanical vibrations</td>
<td>radiation</td>
</tr>
<tr>
<td>animals</td>
<td>work under conditions of overpressure/pressure below the atmospheric</td>
</tr>
</tbody>
</table>

**Table 4.1. Threats or dangerous factors**

For the formwork area, according to table 4.1, the following threats can be listed:

- Mechanical threats
  - Unprotected moving parts (e.g. cutting or fixing points at the joint of two formwork components);
  - Risk of fall (e.g. risk of slipping on the floor formwork upon application of anti-adhesives);
- Dangerous substances
  - Liquids, vapours (e.g. distribution of anti-adhesives);
  - Dusts (dusts emerging during assembly of formwork);
- Cold and hot agents
  - Touching of hot or cold surfaces (using of metal formwork components in the winter or in regions characterised by exceptionally high temperatures);
- Weather conditions
  - Impact of heat/cold: air temperature, air humidity, air velocity, heat radiation (e.g. carrying of slab formwork in the mid-summer);
- Noise

\(^{111}\) BG BAU
o noise emission (e.g. hearing impairment due to high noise level on site, failure to hear a warning);
• Physical loads
  o manual carrying of heavy objects (e.g. manual placement of wall formwork components);
  o enforced body posture (e.g. working with head raised while removing the ceiling system components);
• Psychological pressures
  o work organisation (e.g. shift-based work, stress associated with the necessity to keep the work deadlines on site).

Stage 3: Risk assessment

Occupational risk assessment is based on specification of the probability of emergence of an adverse event (threat) and the amount of losses caused by such event. The product of the two values can be defined as a risk. For practical occupational risk assessment, various methods and auxiliary tools have been devised. Figure 4.7 presents an example of Nohl’s method. The product of probability of emergence of an adverse event (threat) and the amount of losses gives a number from 1 to 7, equal to risk. Value of 1 to 2 represents a low, acceptable risk level. Values of 3 to 4 represent a substantial risk and a necessity to introduce means to limit the threat. Values 5 to 7 represent a high risk level, requiring immediate action to lower the risk level or immediate suspension of works.
Figure 4.7. Risk matrix – Nohl’s method

Stage 4: Specification, implementation and verification of effectiveness of preventive actions.

Figure 4.8 presents an example of a risk assessment sheet for boarding works conducted using frame wall formwork.

Column 1: Definition of threat or dangerous factor
Columns 2-4: Specification of source of threat and consequences
Column 5: Risk value (according to Nohl)
Column 6: Specification of preventive actions to lower the threat to the acceptable risk level or its complete elimination
Columns 7-13: Means of controlling

---

112 Assessment of risk according to Nohl, on the basis of BG BAU
Figure 4.8. Threats and preventive actions on site and their controlling
Stage 5: Documentation of results (protocols, checklists, user manuals, summary documentation)

Occupational risk assessment is one of the basic processes implemented at a company.

In order to rationalise the risk assessment process, it is possible to prepare a basic, internal risk assessment for standard processes which will be updated through adaptation to individual, original conditions of a specific construction task.

4.5 QUALITY MANAGEMENT

4.5.1 QUALITY OF PROCESSES, PRODUCTS AND SYSTEMS IN CONSTRUCTION

DIN EN ISO 9000 defines quality as the "degree, in which a set of inherent characteristics... meets... the requirements".\(^{113}\) It is necessary to distinguish between the physical, sensory, behaviour-related, time-related, ergonomic and functional characteristics. These characteristics are to be understood as either qualitative or quantitative. The requirements with regard to these constitute the conditions or expectations which have been defined, usually assumed or binding. For instance, quality can be assessed in terms of adjectives as being good or bad. Within the framework of designing and implementing a construction facility, quality is one of the parameters which are decisive for success of the construction undertaking. Apart from quality, the aim is to achieve cost- and deadline-related goals. The three target values must be optimised in relation to one another when defining the project success.\(^{114}\) The definition of quality presented above specifies the requirements for individual construction works and the entire system of a construction facility. A construction facility, understood as a system, can be divided into individual components (subsystems) which include: the load-bearing structure, the building coating, development of rooms and technical equipment.

\(^{113}\) DIN EN ISO 9000 (12.05)
\(^{114}\) Pfarr (1984)
These subsystems are further divided into construction groups and components (see figure 4.9).

Figure 4.9. Division of a construction facility as a system into sub-systems and groups of construction components

The quality of a construction facility as a system is a result of correlations between individual construction components which have emerged in the construction facility, as a result of numerous construction planning and implementation processes. Thus, the quality of a construction facility is influenced by the quality of the applicable products and the quality of the process of planning and implementing construction. Thus, for each partial process it is necessary to specify and control the quality requirements (see figure 4.10).

---

115 Klingenerger (2007)
4.5.2 **RULES AND CONDITIONS OF QUALITY MANAGEMENT IMPROVEMENT**

The basic principles and ideal conditions for improvement of quality management within the framework of design and implementation of a construction facility, the following aspects can be distinguished:

- Quality management includes the construction facility life cycle;
- The issue of quality should be present throughout all levels of organisational hierarchy;
- Tasks, competences and responsibility associated with each work position have been properly defined;
- Organisational correlations between the investment participants have been specified and clearly defined, while the competences, quality systems, information exchange systems and further processes and necessary have been regulated and established in this regard;
- The investment participants cooperate with each other, identifying themselves with the general project objectives and the specific quality aspects;
- Each investment participant is aware of their responsibility for the quality of work performed, and thus contributes to improvement of quality of all processes and the entire construction;

---

116 Masing (1994)
Quality-oriented thinking and actions of employees are supported through training, instructions and knowledge management;

The proper quality of implementation of construction processes is supported by preventative actions;

The issue of avoiding errors and identifying and detecting defects (mistakes) and identification of their causes is treated as a priority;

All of the design and implementation processes will be appropriately documented;

Carefully conducted design processes and the proper production preparation serve as a basis for the appropriate implementation quality;

The proper price level and satisfactory employee remuneration warrant their proper motivation;

Adequate construction implementation time limits the sources of errors;

Cleanliness and order at work and compliance with occupational health and safety on the construction site, as well as good cooperation between the companies involved are components that support the quality.\textsuperscript{117,118,119}

The selected aspects of quality management have been presented in the following subchapters:\textsuperscript{120}

- Control of contract documents;
- Control of design processes;
- Conducting meetings on site;
- Recruiting subcontractors;
- Control of preceding works of other (sub)contractors;
- Defect-related claims.

It is necessary to follow and take into account the legal conditions applicable in the country in which a given construction undertaking is being implemented.

\subsection{4.5.3 Control of contract documents}

After the order is granted and the contract for construction works is concluded, within the framework of commencement of the building permit design, the task of

\textsuperscript{117} Deutsche Gesellschaft für Nachhaltiges Bauen [German Society for Sustainable Construction] (publisher, 2009).

\textsuperscript{118} Klingenberger (2003)

\textsuperscript{119} Vogdt et al. (2002)

\textsuperscript{120} Cichos (2007)
the construction management for a given contractor for works is to control the contract documents from commencement of works aimed at preparation of production. For this purpose, internal interviews are conducted with persons involved in the bid preparation, calculation and acquisition. During these activities, a control of completeness of documents is conducted (see figure 4.11). It is also necessary to make sure that the letters (certificates) provided are really binding documents. This is confirmed by manual initialling of all components of the contract (each page and each plan) by the contract parties. Unless it is clearly confirmed, it should be clarified whether a given component belongs to the agreement. In general, contract documents for construction works consist of the following components:

- Contract for construction works with protocols of all negotiations that exert impact on the contract conditions;
- Subject and scope of the contract, specification of works;
- Documentation (plans, calculations, clarifications, schedules);
- Available opinions (if any);
- Any permits of administrative bodies (e.g. the building permit);
- Information on the land plot survey (boundaries, fixed elevation points) and the main axes of the construction facility;
- Authorisations and powers of attorney of the project participants;
- Information on the current condition of: the land plot, the land plot infrastructure (transport, utilities, waste removal), condition of neighbouring developments;
- Calculation (cost estimate);
- Earlier contracts concluded by the contractor with subcontractors (if any).

Missing contract documents should be added. Apart from control of their completeness, it is necessary to critically assess the content of contract documents with regard to any discrepancies. In the first place, the building permit design, provided by the ordering party, should be analysed, among other things, in terms of the following:

- Compliance with legal provisions, regulations and technical knowledge principles;
- Compliance with the building permit design conditions;
- Technical feasibility.

If a risk of occurrence of defects or errors is found, or in the case of objections with regard to the planned mode of implementing construction works, the ordering party should be informed of these in writing.
Figure 4.11. The process of control of the order documents

4.5.4 CONTROL OF DESIGN PROCESSES

Implementation of construction works takes place on the basis of the building permit design, which includes the spatial development project, the architectural and building design and, as necessary, other documents, such as results of geotechnical surveys. The results of design processes constitute a necessary and binding source of data and information for the contractor on implementation of the construction project. Depending on the contract conditions, some of the design tasks may be implemented by the contractor. Regardless of this, the design processes should be subject to control analogous to production processes. This means that both the level of advancement of design works and delivery of detailed documentation to the construction site should be monitored. Figure 4.12 presents the procedure for control of the design process. Receiving a specific fragment of the design
documentation is confirmed by the contractor on the so-called documentation intake lists, specifying the receipt date. Afterwards, the documentation is verified with regard to:

- Completeness;
- Acceptance by the ordering party/investor;
- Compliance with the contract;
- Compliance of the content with other /earlier plans;
- Readiness of plans for implementation.\(^{121}\)

Document control is of utmost importance in the case of the so-called fast track projects, which are often implemented nowadays. In this case, planning is conducted during construction.

![Diagram](Figure 4.12. Procedure of control of the design process)

\(^{121}\) Vygen/Schubert/Lang (2008)
4.5.5 Conducting Construction Meetings

Meetings and consultations are important modes of communication between the project participants when it comes to construction undertakings. Spontaneous meetings and formalised meetings can be distinguished. When the participants want to conduct a meeting to attain specific goals, the possibility of efficient clarification of questions and problems associated with progress of construction works is undoubtedly an advantage. Appropriate preparation of a meeting is aimed at effective presentation and discussion of individual issues. The participants are to be invited to attend the meeting and provided a specific agenda (see figure 4.13). In an ideal situation, materials serving as a basis for discussion and decision-making are distributed in advance. In the case of regular meetings, open agenda items from previous meetings should be raised again. Since oral arrangements are not recorded and cannot be proven, the results (decisions and division of works) should be summarised in a protocol. A meeting protocol should be distributed among all participants to be confirmed by them; in case of any objections, it should be prepared again for confirmation. Summing up, meetings are the proper way to reach agreement with regard to the planned condition of the construction structure and the attained quality.122,123

122 Klingenerger/Selz (2006)
123 Klingenerger/Selz (2006)
Figure 4.13. The process of construction meetings

4.5.6 RECRUITMENT OF SUBCONTRACTORS

If individual scopes of works should be or must be performed by contractors (in the latter case, nominated subcontractors), assuming that involvement of subcontractors is allowed for in the contract, it is necessary to find the appropriate company and entrust it with a specific scope of works. In order to organise a tender, it is necessary to prepare the appropriate documents. The scope of works and contract conditions offered to the subcontractor should be compliant with the logic of the scope of works and contract conditions of the contractor (e.g. the general contractor). To this end, it is necessary to check the contract document, taking into account the following aspects:

- Are the existing documents complete?;
Has the facility planned been clearly and fully defined and described?
Are there any discrepancies between the individual documents?
Have the organisational links with other scopes of work (works of other subcontractors) been clearly defined?
Are the implementation term and deadlines feasible?
Has a quality management procedure been specified (e.g. control procedures)?

The prepared and checked documents are used to organise a tender for the scope of works specified or to make an inquiry to the potential subcontractors, asking them to present their bids. Unlike public and sectoral entities, private investors can freely choose from bidders for works to be subcontracted and negotiate the scope and price for works. Subcontractor bids are reviewed, analysed and checked in terms of their technical, economic and quality aspects and assessed accordingly. The lowest price should not be the decisive criterion. Taking into account the need to assure the quality of the entire facility, it is necessary to select a bidder who is generally qualified to perform the works assigned, that is, warranting the efficient implementation with regard to professional, technical and quality aspects, whose bid is at the same time the most cost-effective one. The exemplary criteria for assessment of bid variants can be as follows: technical value, appearance, feasibility, environmental impact, costs of operation of the facility and the associated costs, profitability, customer services, technical assistance, deadline and quality.

4.5.7 CONTROL OF WORKS PERFORMED EARLIER BY OTHER (SUB) CONTRACTORS

If the scope of works to be performed relies upon works of other (sub) contractors recruited by the ordering party, these works should be controlled prior to commencement of own implementation processes (see figure 4.14). Defects found during such control are to be reported to the ordering party. Further proceedings depend on the individual contract conditions and the decision of the ordering party. Usually, the contractor, who performed the works, is responsible for elimination of defects. After they are eliminated, the condition of the task should be controlled and documented.\textsuperscript{124}

\textsuperscript{124} Duve/Cichos (2008)
Figure 4.14. The process of control of preceding works of other (sub) contractors

4.5.8 CLAIMS RELATED TO DEFECTS

Claims related to defects will be settled in accordance with the framework legal conditions applicable to a given construction market, and the individual contract conditions for a specific construction undertaking.

The defects found should be documented. Afterwards, in consultation with the ordering party and the contractor, it is necessary to decide whether the defects will be eliminated or accepted by the ordering party, specifying the conditions of such acceptance. This option is possible and it is applicable to the building practice. Withdrawal from elimination of defects usually refers to minor defects which are of no significance in terms of safety and functioning of the facility. Such defects can be classified as disproportionate, since the financial expenditures required for their elimination are not consistent with the added value of the condition of the facility without defects. Withdrawal from removal of defects is usually associated with reduction of the contractor’s remuneration. It should also be determined
whether a given defect is a result of design errors or works of other (sub) contractors. Regardless of who is responsible, it is necessary to control and document the results of defect elimination. If defects are not eliminated effectively, the entire process should be repeated.
CHAPTER 5

LEAN CONSTRUCTION – INTRODUCTION
(C. MOTZKO, F. BINDER)

5.1 LEAN THINKING AND LEAN MANAGEMENT

The "lean" terminology is currently used in the context of defined concepts and methods of simple and clear (“lean”) organisation of processes, which may refer to production, management or administration. It is associated with lean thinking and lean management terminology. Lean management can be divided into lean production, lean development and lean administration. The basis for the modern lean production philosophy is offered by Toyota Production System (TPS). One of the fundamental components of TPS is elimination of waste, which should result in shortening the production cycle, improving production quality, reducing costs and improving mutual coordination and communication between employees. For construction, the lean construction concept is discussed in Chapters 5.2 and 5.3.

Lean thinking. Lean thinking emerged in those branches of industry which operate on a fixed, regular basis. “It shows the way to recognise the value, the continuous performance of tasks that create value always, when there is demand for it, and the fully effective implementation of value”125. At the core of lean thinking is the concept of elimination of waste from production, management of work deadlines, human resources, construction processes, production means, machines, and

equipment and construction materials. The “muda” phenomenon in production processes was discovered by Taiichi Ohno (1912-1990). Muda includes:

- Defects of products that are qualified for elimination;
- Production of items for which there is no demand, resulting in ever-increasing stock;
- Implementation of processes which are not effective and efficient;
- Unplanned movement of personnel and unnecessary transport of materials to another place without a specific objective;
- Employees waiting upon subsequent production processes due to delays occurring at the preceding workstations;
- Goods and services that do not meet the expectations of clients.

Lean thinking is subject to five key principles:

1. **Definition of value.** Definition of value serves as a basis for lean thinking. The value of the product (e.g. the construction facility) is specified in accordance with the criteria of the client, adapted to their needs and manufactured by the producer. The process of value definition should be synchronised, if value is created by many companies. Various objectives of various companies involved may lead to conflicts which are associated with risks of a failure to meet specific value requirements. On the other hand, there is a chance that proper application of lean thinking in an organisation oriented towards value, resources will be released to improve its effectiveness. Thus the methods of organisation of processes and structures should be linked to economic analyses in relation to the definition of value.

2. **Identification of the total value stream for every product.** The value stream consists of all required specific activities, allowing for leading a given product (e.g. a construction facility) through three areas of management: design (concept, structure, preparation of production, launching of production), management of information (ordering, establishing of deadline, delivery) and transformation (from raw material to finished product). Within the framework of the value stream analysis, various categories of activities can be established. These include:
   - Value creation activities (the main process): from the client’s perspective, they lead to increase of value. Thus, they increase the value of the product (e.g. construction facility) for the client throughout the process. These activities should be subjected to scheduled and continued optimisation. Examples of activities that
create value are: construction, assembly, processing and means of increasing the “ideal” value of the product (marketing);

- Activities which do not create value, but are (still) necessary (auxiliary processes): these contribute only indirectly to an increase in the value of the product (e.g. a construction facility). They support the value creation activities, and therefore they are also referred to as supporting works. These include: preparation of machines, internal transport, planning and control of production, preparation of reports and statistics (controlling);

- Activities which do not create value (unproductive and erroneous activities – waste): these are the activities which are usually unplanned; they do not contribute, either directly or indirectly, to product value creation. These include erroneous activities (including those from the first two categories) which cannot be used because of the errors or defects that occurred in the process of their implementation. Examples of such activities are: temporary storage, discontinuation of production due to shortage of parts, additional works, disturbances, late deliveries due to erroneous information, removal of defects (unplanned).

3. **Continuous value flow** (flow of activities that generate value for specific products). The aim of continuous flow is to generate the value of the product (e.g. a construction facility) in an even manner. With reference to the organisational structure, this leads to creation of specific (individual) teams for every product having the appropriate qualifications for the value creation process. It is necessary to apply the appropriate decision-making methods in a team. An example here may be the Quality Function Deployment. For the appropriate production process, it is necessary to define the production batch. Within the framework of methodology, it is possible to apply the principle of belt-system production, in which individual production stages are implemented continuously in a specific order, while the resources are being consumed evenly. This principle is supported by the “just in time” methodology. This methodology, in the context of production, means that procurement is synchronised with production. It is a production and logistic strategy aimed at creation of overall flows of materials and information along the value creation chain, which is aimed at quicker completion of order and increasing of their flow speed.¹²⁷

---

¹²⁷ Pfohl 2000
4. *The "pull" principle.* The "pull" principle means that the latter production unit is supplied by the preceding production unit with the operational means as necessary. As a result, the process speed is defined by the latter production unit. This results in reduction of stock levels.

5. *Aiming at perfection.* The entire organisation works on concepts of products and production which allow for elimination of waste (*muda*). The number of errors should be constantly reduced. It is necessary to eliminate system failures, quality deficits, standstills etc. This requires devising processes and instructions that are clear, allow for definition of target conditions and warrant specification of current conditions in a manner that allows for their active control and modification. Through critical control of activities we obtain an increase in the share of value generation within processes. Emphasis is put on those processes which generate value and thus increase benefits for clients (internal/external). To this end, all activities which are not necessary are systematically detected and limited or eliminated. As a result, the process costs are visibly decreased.

The basic impulse for devising and implementation of such lean production philosophy originated at the Toyota Production System (TPS) car factory, when the then-director, forced to introduce savings, reduced the production resources by 25% (that is, the production area, the investment planned and staffing).

"All we do is control the project duration time, from the placement of the order until receipt of payment. In addition, we shorten the time designated for the project implementation by removing all the unnecessary activities, which bring no benefits, from the process."[128]

The basic TPS components are:
- **Just in Time.** Just in Time means, in general, that the appropriate part of production is available at the appropriate time, in the required quantity and quality and in the right place. The dominant principles are the pull principle, meaning that the successor obtains the appropriate quantity of the product from the predecessor, and then the principle of constant flow of value, that is, coupling the processes of value generation and reduction of the production batch size. The third principle is that of even work, that is, synchronisation and division of a construction facility into work sections, maintaining a relatively even level of labour demand for each of these;
Quality and stability. These include, in the first place, the principle of error prevention. This has been applied in such methods as 5S, Poka Yoke or TPM. It is about early detection of errors during implementation and their early reporting. Permanent elimination of errors can be achieved thanks to such methods as 5W or Kaizen (“constant improvement”);

Constant improvement. Products, processes and qualifications of employees must be constantly developed and improved. This is supported by the KAIZEN principle of continuous improvement and aiming at perfection of processes using the so-called philosophy of small steps. Within the framework of the KAIZEN philosophy, in a given corporation, any employee may report proposals/remarks concerning changes, which are always considered by the superiors. The employees do not have to fear any disciplinary sanctions or loss of their jobs.

Employees and partners in the culture of the corporation. Employees are at the core of the organisational culture. In TPS this means, among other things, that the management is present where value is generated. The high quality requirements are demanded also from their partners and sub-suppliers. This improves the necessary stability of processes. As for sub-suppliers, the principle of long-term partnership and continuity is applied.

It is a good idea to become familiar with specialist literature on the subject.

**Lean Management.** The central part of the lean management idea is generation of value and elimination of any waste which emerges within the framework of manufacturing of goods and services. All activities and resources which are not necessary to raise the quality of the product are considered to be unneeded and should be eliminated, like the stock levels and materials stored, waiting for processing. The target increases in production capacity, as well as faster production, are significant factors in terms of competition and market share. At the same time, well-organised and flexible production allows for manufacturing of individualised, specific products of the highest quality. In practice, this means application of selected principles, methods and means, which are to be positioned in between the strategic and operational perspective.
5.2 LEAN CONSTRUCTION

Introduction. The lean management philosophy, after some modifications, can be applied to the construction industry under the term “lean construction.” Translation of the ”lean” concept to construction (described in chapter 2.1) depends on modification of the methods which were devised for regular, fixed-basis industries as needed due to the specific nature of construction, thus:

- Limiting waste;
- Structuring the product value generation processes (e.g. in terms of a construction facility);
- Partnership-based cooperation.

In the context of lean construction, it is necessary to mention Laurie Koskela, who, in the early nineties, dealt with application of lean management in construction. He stated that it was necessary to complement the transformation aspect (input-output relations) of the construction manufacturing process by adding the component of flow of activities, resources and information, as well as understanding of value (TFV theory, see figure 5.1).

---

130 Koskela, J.: Application of the New Production Philosophy to Construction, 1992
The principles. Lean construction is conducted in accordance with similar principles to those of lean thinking:

- Elimination of waste. Application of lean construction is justified by various weaknesses of construction work processes, which include:
  - High levels of material stocks on site. These result in unnecessary long-term “freezing” of capital, they lead to unnecessary logistic processes and potential damages, e.g. due to unfavourable weather conditions;
  - Maintenance of too large, badly organised warehouse areas. This leads to disturbances in the flow of materials and loss of time due to searching for those materials which are needed at the time;
  - High susceptibility of construction manufacturing to defects. The lists of faults which are made during acceptance, sometimes reach several thousand items. These are partially due to insufficient qualifications of

---

131 Kaiser, J. 2011
the work teams engaged, or due to insufficient supervision of the work processes;
  o Insufficient preparation of production. In many construction companies, due to limited staffing of the production preparation department, it is impossible to warrant the appropriate production planning on site.

- Constant process flow. The aim of this principle is to establish a production structure in accordance with the assumptions of even work methods. By dividing the facility into small work sections, it is possible to eliminate activities that do not generate value. Moreover, continuity and eveness of employment of work teams is ensured. Identification of reserves allows for reduction of the production cycle. The reserves include:
  o Time reserves. Preparation of the work schedule is associated with planning a time reserve for individual tasks. These reserves are necessary due to uncertainty of the predicted weather conditions, untimely delivery of materials and services and other factors. Without proper control, it is impossible to use and transfer these reserves from one activity to another;
  o Space reserves. Use of space for production purposes and for storage is more effective if continuous process flow is ensured;
  o Reserves of means. Excessive reserves of means can be detected more easily and quickly if continuous process flow is ensured.

- The “Pull” principle. This principle is based on the Japanese “Kanban” method (“visible description”). The method allows for visualisation of flow of construction materials on the site. It is aimed at control of production processes, focused on the necessary and real consumption of materials in the place of assembly. The latter production unit is supplied by the preceding unit only with the necessary operational means. As a result, it is possible to improve the construction manufacturing processes through reduction of complexity. Logistic processes and construction and assembly production processes are operating in accordance with the “signal given” and they are understood as a system in the sense of a control loop. This allows for avoidance of large stock accumulation. The “pull” method allows for reduction of susceptibility of construction works to the potential disturbances of construction processes. For instance, auxiliary processes are activated when they become necessary for implementation of basic processes (Just-in-Time). In such case, the potential disturbances in basic processes have no direct impact on auxiliary processes. This allows for reaching greater flexibility. In the case of fluctuations of capacity, it is possible to regulate the inflow of means directly.
• **Constant improvement.** The Japanese “Kaizen” philosophy is based on the assumption that everything requires improvement and the standards achieved can be made better. In terms of construction manufacturing, it can be stated that the appropriate strategies are established, but usually they are not implemented to the sufficient extent. Construction is still struggling to attain the highest quality of performance, specified in the contrast. It may be helpful to apply long-term process optimisation methods, such as:
  o Introduction of the so-called Best Practice, such as the PDCA system (Plan-Do-Check-Act, see Manual M13);
  o Ensuring the flow of information from the entire corporation (all construction sites) to each site, e.g. within the framework of the Project Communication Systems (see Manual M10);
  o Professional development of employees, who are at the core of the corporation profile and culture.

• Documentation of processes. Implementation of lean construction requires a high degree of clarity of processes due to application of the appropriate control methods. The level of advancement of processes and the possible defects or disturbances in implementation must be specified and documented, taking into account the advancement of the schedule, costs and quality problems. This can be attained e.g. by:
  o Defining processes necessary to manage a given construction site which is associated with specification of the appropriate indicators and means of control and reporting;
  o Applying proper means for systematic information gathering on the condition of building processes (progress of works), e.g. various sensors;^{132}
  o Application of means for organisation, use and analysis of data (information) on the condition of processes (progress of construction works) (see Manual “Computer Methods in Construction”).

• Cooperation. Implementation of lean construction requires strict cooperation with various project partners. Within the framework of a given project, it is necessary to organise the non-uniform group of participants of a construction undertaking so that, assuming the proper division of works, competences and responsibility, all of the necessary design and production processes are implemented on time, assuring the appropriate quality, within the framework of the budget specified. Organisational structures and processes are characterised by a substantial number of organisational links which, in the first place, have to be properly defined (see chapters 1 and 2).

---

^{132} Motzko, C. et al. (2007); Pflug (2008)
Methodology (example). One of the methods of application of lean construction is the so-called last planner system. The central component of this method is the organisation or person acting as the last planner, who operates in between the construction planning and manufacturing processes, and, depending on the level of advancement of construction works or the condition of the detailed design documentation, confirms continuation of the production processes. In the so-called “look ahead” plan, activities are defined for the next 4 to 6 weeks, serving as a basis for a weekly work plan. The construction management and the designers, cooperating closely, approve the implementation of the investment stages, for which it has been assured that the design process has been fully completed. In particular, in construction projects, in which specific design processes take place simultaneously to construction (fast track projects), systematisation of processes as described above is highly reasonable. The measure of progress in design and implementation of construction works is the percent plan complete, a quotient of tasks completed to the total number of tasks, specified in the weekly work plan.

Remarks. When lean construction is applied, the core element should always be the employee. Work time organisation is a significant component of occupational health and safety. Limitation of the scope of work, organisation of work division (e.g. during the day) and the associated difficulties at work are only selected components of the processes of organisation of construction works. Rationalisation methods in work processes must be introduced taking into account the work organisation, which has been materially and professionally justified. From the perspective of construction, in the organisation of work duration it is necessary to take into account the binding provisions of the act on collective work agreements. Therefore, according to the legal provisions in force in Germany [Tarifrecht], the work time indicator tables, approved by parties to the collective work agreement serve as a basis for the corporate division of production processes (the area of piece wages). These were prepared in accordance with the labour science methodology and they are representative of processes on ordinary construction sites.

The work time indicators for general construction industry (ARH tables\textsuperscript{133}) provide for:
10\% time for rest;
20\% additional time (unplanned waiting time, additional tasks, personal breaks e.g. toilet);
70\% basic time (main task + auxiliary task + planned waiting time).

\textsuperscript{133} Handbuch Organisation Bau
In the case of a boarding work team, the main tasks include:

- Transport of wall formwork within the construction site;
- Placement of formwork and assembly of joints;
- Placement of supports, evening out of formwork;
- Assembly of work scaffolding.

Auxiliary tasks include:

- Cleaning;
- Putting in order.

Main and auxiliary tasks serve the implementation of the work task directly or indirectly. In construction, these are the activities that generate the value of the product (e.g. the construction facility). These include the logistics, carried out according to the plan (e.g. transport of formwork). It is always the necessary component of the production process, since the construction facility (or its part) usually meets the conditions of the agreement only within the framework of specific spatial coordinates (value generation), regardless of the principle of performance of works. Time for rest is necessary and obligatory. Construction works belong to the category of hard physical work. They are characterised by multiple load, such as carrying of heavy weights, exposure to cold and unfavourable weather conditions, piecework system, exposure to dust and noise, as well as emission of other substances (see figure 5.2).
Figure 5.2. Physical load of work and requirements to be met by men at work

High loads are associated, in particular, with shell state facilities; the work tasks of concrete placers, carpenters and scaffolding assembly workers. Works of these groups are categorised as “hard” (see table 5.1).

---

Hartmann/Seidel (2007)
<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Loads Up to 10 kg</th>
<th>10-25 kg</th>
<th>Above 25 kg</th>
<th>Work performed with difficulty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installers</td>
<td>519</td>
<td>9.8</td>
<td>37.5</td>
<td>48.4</td>
<td>16.4</td>
</tr>
<tr>
<td>Bricklayers</td>
<td>539</td>
<td>3.5</td>
<td>33.4</td>
<td>51.6</td>
<td>26.2</td>
</tr>
<tr>
<td>Concreters</td>
<td>112</td>
<td>4.5</td>
<td>30.4</td>
<td>59.8</td>
<td>32.1</td>
</tr>
<tr>
<td>Wood-workers</td>
<td>192</td>
<td>3.6</td>
<td>27.6</td>
<td>60.4</td>
<td>21.9</td>
</tr>
<tr>
<td>Roofers</td>
<td>308</td>
<td>8.4</td>
<td>34.7</td>
<td>53.2</td>
<td>15.3</td>
</tr>
<tr>
<td>Scaffolding installers</td>
<td>76</td>
<td>1.3</td>
<td>22.4</td>
<td>73.7</td>
<td>34.2</td>
</tr>
<tr>
<td>Road workers</td>
<td>67</td>
<td>1.5</td>
<td>37.3</td>
<td>56.7</td>
<td>23.9</td>
</tr>
<tr>
<td>Assistants</td>
<td>143</td>
<td>7.0</td>
<td>32.9</td>
<td>54.5</td>
<td>18.9</td>
</tr>
<tr>
<td>Insulation/ drywall installers</td>
<td>143</td>
<td>11.9</td>
<td>35.7</td>
<td>45.5</td>
<td>16.1</td>
</tr>
<tr>
<td>Glazers</td>
<td>81</td>
<td>1.2</td>
<td>49.1</td>
<td>45.7</td>
<td>24.7</td>
</tr>
<tr>
<td>Interior finishing workers</td>
<td>71</td>
<td>2.8</td>
<td>38.0</td>
<td>57.7</td>
<td>14.1</td>
</tr>
<tr>
<td>Carpenters</td>
<td>57</td>
<td>8.8</td>
<td>36.8</td>
<td>45.6</td>
<td>10.5</td>
</tr>
<tr>
<td>Painters</td>
<td>404</td>
<td>11.4</td>
<td>64.9</td>
<td>20.0</td>
<td>14.9</td>
</tr>
<tr>
<td>Construction machine operators</td>
<td>51</td>
<td>17.6</td>
<td>21.6</td>
<td>39.2</td>
<td>21.6</td>
</tr>
<tr>
<td>Cleaners</td>
<td>94</td>
<td>40.4</td>
<td>29.8</td>
<td>13.8</td>
<td>11.7</td>
</tr>
<tr>
<td>Office workers</td>
<td>112</td>
<td>26.8</td>
<td>18.8</td>
<td>12.5</td>
<td>9.8</td>
</tr>
<tr>
<td>Construction professions group N&lt;50</td>
<td>181</td>
<td>11.6</td>
<td>26.5</td>
<td>56.4</td>
<td>26.0</td>
</tr>
<tr>
<td>Total with other profession</td>
<td>3413</td>
<td>9.5</td>
<td>36.7</td>
<td>45.5</td>
<td>19.5</td>
</tr>
</tbody>
</table>

**Table 5.1. Loads associated with carrying of heavy weights by men**

Research results, which have been confirmed by practice and published, show that long periods of work may lead to serious health deterioration, intense stress and tiredness symptoms. At the same time, the risk of accidents increases. Discussion of the possibilities of rationalisation in the area of personally conditioned work breaks is taken into account in the additional time category; however, due to physiological reasons, it cannot be disregarded. Work breaks during the basic work times which are dependent on the course of construction processes, reflect the current state of technological progress, and thus they are a function of the technology applied.

---

135 Hartmann/Seidel (2007)  
136 Arbeitswissenschaftliche Erkenntnisse (2002)
Presented below is the BPS, the construction process system used in building practice (see figure 5.3), which has been devised in accordance with the lean construction principles.\textsuperscript{137}

The BPS construction process system is divided into three planes: objectives, processes and methods and principles. Innovation of this approach is due to the fact that in the area of processes and methods, a combined structure of three planes has been defined: order completion management oriented at processes, operational management of performance and systematic constant improvement. The structure is explained below and its significance is illustrated by a practical example.

\textsuperscript{137} Kaiser, J. 2011
### System of construction processes

<table>
<thead>
<tr>
<th><strong>Objectives</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
</tr>
<tr>
<td>Transparency</td>
</tr>
<tr>
<td>Flexibility</td>
</tr>
<tr>
<td>Reporting</td>
</tr>
</tbody>
</table>

### Processes and methods

**Process-oriented management of completion of orders**

- Description of processes
- Project organization
- Reporting

**Systematic constant improvement**

- Optimization process
- Improvement organization
- Standardization

**Operational management of implementation**

- Planning and control of balanced work
- Planning and control of quality
- Planning and control of material flow

**Indicators and visualization**

### Rules

- Separation of value generation and waste
- Value creation is the core issue
- Partnership-oriented attitude and cooperation
- Lean-based processes

---

*Figure 5.3. Structure of the construction process system in accordance with the lean methodology*[^138]

[^138]: Kaiser, J. 2011, also Porsche Consulting
Systemic plane of objectives. At the core of the BPS system of objectives is the client and the issue of compliance with their needs and expectations. This basic objective serves as a basis for introducing the following partial objectives:

- **Effectiveness**: increased effectiveness of processes to reduce the construction costs, e.g. through limiting waste in the implementation of work processes;
- **Clarity**: to warrant the overall, systematic action, it is necessary to define the construction processes clearly. The following components are necessary to achieve this objective:
  - Precise definition of the position and competences of the employee in the project organisation;
  - Devising the proper monitoring tools to obtain an image of the status of implementation of processes, e.g. through specification of the appropriate process indicators;
  - Introducing methods of visualisation, allowing communication of the process status to employees directly and on the site;
  - Formulation of the information flow system.
- **Flexibility**: construction organisations are sociotechnical systems which allow for implementation of complex and dynamic process structures. Thus, cooperation requires high flexibility of the project participants to make sure that the necessary means of control of specific processes are implemented on time;
- **Stability**: processes in construction projects should be implemented stably. Such factors as weather conditions, the right of the ordering party to make changes in the scope of works, unexpected soil conditions or withdrawal of subcontractors require the tools and methods for standardisation of the process implementation.

The systemic plane of principles. The systemic plane of principles along with its components reflects the lean management perspective, thus:

- **Separation of value generation from waste**: value generation in the economic sense is defined as the difference between the production value obtained and the works performed earlier. Within a corporation and within the framework of the process of implementation of a specific construction project, it is necessary to develop the awareness of employees of the objective (high significance) of their works, which generate a combined value (e.g. of the construction facility) from the perspective of the client. It is necessary to distinguish activities associated with increase

---

139 Gabler Wirtschaftslexikon
of value (basic processes, resulting in direct increase of value), hidden waste activities (auxiliary processes which are necessary to conduct the basic processes without generating direct increase of value for results) and open waste activities (e.g. waiting time due to disturbances);

- Centralisation of value generation: orientation of the enterprise on the process of value shaping. Moreover, focus on the place of value generation. In the context of the above discussion, particular emphasis should be put here on the issue of the construction site, discussed in chapter 4;

- Partnership-based cooperation: in the sociotechnical system of the construction project, in order to implement it efficiently, it is necessary to establish a link between the essential qualifications of employees within the framework of the enterprise. This pertains to relations with the ordering party and the appropriate offices, as well as all subcontractors, suppliers, designers and other external entities;

- Organisation of processes according to lean methods: in relation to the construction site, it is necessary to ensure solid representation of work gangs, since the workplaces are “mobile” within the structure of the facility under construction. It is also necessary to define the work sections according to the target dimensions defined. Particularly significant is the process planning according to the principle of even distribution, on one hand it is necessary to even out the use of resources, on the other hand to ensure flexibility of performance of works in the case of disturbances. This can be attained thanks to the “pull” principle. In particular, the project management and the next work gang should be informed of completion of individual processes. Thus, at least partially, we attain the distribution of raw materials and operational means as necessary. The last component of the rule is aiming at perfection, that is, constant development and improvement of the construction work processes.

The systemic plane of processes and methods. Objectives and principles are implemented on the plane of processes and methods. This is a dynamic structure, within which there is interaction between operational management of performance of works, which is process-oriented, and management of the order completion. This interaction is regulated by systematic improvement of the flow and organisation of construction works in accordance with the principle of Continuous Improvement Process CIP (KVP Kontinuierlicher Verbesserungsprozess). The components of this system plane are:

- Process-oriented management of order completion. It is subject to two principles: process-orientation and the so-called “front loading”, which is based on early, careful analysis of tasks, along with specific planning of production in order to identify quickly the weaknesses, as well as the
existing potential. A description of the construction process can be attained e.g. on the basis of a schedule of implementation of subsequent stages of construction works. An adequate example has been presented in figure 5.4. Apart from standard components, such as the project implementation stages and milestones, the so-called “quality gates” are of significance. They establish milestones, used to check whether all of the tasks mentioned have attained the required status in terms of progress and quality of works. Only after all conditions are met, the next stage can be launched. Standardised reporting is a significant component of these planes.

![Construction of a map of processes for management of completion of the order](image)

**Figure 5.4. Example of a process map**

---

Kaiser/Khodawandi 2008
• Operational management of implementation. Operational management of implementation refers directly to the stage of preparation of works and the entire construction process. At the core are the production processes. Individual undertakings are subordinated to the common goal: efficient and effective implementation of the construction facility. A significant aspect is continuous production, understood as even work distribution. The appropriate methods of operational management of construction undertakings and their implementation are described in the appropriate literature on the subject.

As a result, precise weekly schedules for implementation of works should be established for all work teams, providing a specific reference to the production process. In order to adapt and verify the progress of the implementation and production processes, it is necessary to conduct meetings, as explained in the last planner system methodology, presented above. The appropriate qualification methods will allow for establishment of self-controlled, autonomous work gangs, able to determine their work progress independently on the basis of the appropriate visualisation media. A visualisation medium is a very significant component of work on a construction site. Advancement of specific sections of works should be discussed directly on the site, so that the project participants can talk about the important parameters such as the deadlines, cleanliness and order on site, the quality, general information and the appropriate indicators.

Figure 5.5 presents collectively the principles and factors decisive for success of the lean construction methodology.
Figure 5.5. Application of rules and factors that are decisive for successful implementation of lean construction\textsuperscript{141}

Introduction of a production system based on lean construction, and thus initiation of components of a learning organisation in a construction enterprise, is a substantial challenge. In the first place, it is necessary to make or at least stimulate the entire organisation to become ready for changes. The normative, strategic and operational management processes should be controlled in terms of their mutual cohesion. As for the basic processes, various changes will take place thanks to use of new, different methods and tools of management and modern methods and processes of communication. Moreover, it is necessary to commence the implementation of the entire construction process in accordance with the principle of Continuous Improvement Process (CIP). In addition, the entire construction enterprise as an organisation should dispose of the qualified management staff and personnel prepared to implement the construction works planned. Of course, all these activities require the appropriate financial expenditures as well.

\textsuperscript{141} Kaiser (2008)
BIBLIOGRAPHY

Arbeitswissenschaftliche und arbeitsmedizinische Erkenntnisse zu überlangen Arbeitszeiten, Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, 2002


BMVBS Deutsches Gütesiegel Nachhaltiges Bauen

Bürklin, B., Motzko, C.: HOCHTIEF Nachrichten 1/93


DIN EN ISO 9001:2008-12


Engelmann 2005


Gabler Wirtschaftslexikon


Glinz, M.: Informatik II: Modellierung, Univ. Zürich, 2005


GSV Empfehlungen zur Anfertigung einer Gefährdungsbeurteilung bei der Anwendung von Schalungen, Güteschutzverband Betonschalungen e.V., Ratingen/Darmstadt, 2007


Handbuch Arbeitsorganisation Bau 1.03 Richtzeiten Schalarbeiten mit loser Schalhaut, ZTV Verlag, Neu-Isenburg


Hertle, R., Motzko, C.: Gerüstbau, Betonkalender 2007, Ernst & Sohn

Horváth, P.: Controlling. 2008

IPC 2007, Verminderung des Klimawandels, Vieter Sachstandbericht


Mitręga, E.: Kontrakty budowlane - prawne i organizacyjne aspekty planowania kontraktów, 2008


Motzko, C.: Spezielles Bauprojekt, Institut für Baubetrieb, Technische Universität Darmstadt, 2009

Motzko, C., Mehr, O., Bergmann, M.: Echtzeitsteuerung von Bauprozessen

Motzko, C., Mehr, O., Bergmann, M., Boska, E., Boska, P.: Eine Ontologie für die Baubetriebswissenschaft, Institut für Baubetrieb, Technische Universität Darmstadt, 2010


Pieper, R.: Arbeitsschutzrecht, Bund Verlag, 2009


REFA in der Baupraxis, Teil 1, 1984


Rundnagel, R.: www.ergo-online.de

Seidlmeier, H.: Prozessmodellierung mit ARIS, Vieweg, 2002
Womack, J. P., Jones D. T.: Lean Thinking, Campus 2004
Vygen, K.: Bauvertragsrecht nach VOB, Werner Verlag, 2007