VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

Martin Wolfgang SCHIEG

MULTIPLE CRITERIA ANALYSIS OF CONSTRUCTION PROJECT MANAGEMENT

DOCTORAL DISSERTATION

TECHNOLOGICAL SCIENCES,
CIVIL ENGINEERING (02T)

VGTU
LEIDYKLA
Vilnius TECHNIKA 2010

Doctoral dissertation was prepared at Vilnius Gediminas Technical University in 2010.
The dissertation is defended as an external work.

Scientific Consultant

Prof Dr Habil Romualdas GINEVIČIUS (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T).

VGTU leidyklos TECHNIKA 1783-M mokslo literatūros knyga
http://leidykla.vgtu.lt

ISBN 978-9955-28-632-5

© VGTU leidykla TECHNIKA, 2010
© Martin Wolfgang Schieg, 2010

VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

Martin Wolfgang SCHIEG

DAUGIAKRITERINĖ STATYBOS PROJEKTO VALDYMO ANALIZĖ

DAKTARO DISERTACIJA

TECHNOLOGIJOS MOKSLAI,
STATYBOS INŽINERIJA (02T)

LEIDYKLA
Vilnius TECHNIKA 2010

Disertacija rengta 2010 metais Vilniaus Gedimino technikos universitete.
Disertacija ginama eksternu.

Mokslinis konsultantas

prof. habil. dr. Romualdas GINEVIČIUS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, statybos inžinerija – 02T).

Abstract

The dissertation investigates management of construction project, that of the participating and pursuing the aims interested parties and that of external macro-micro environment influencing the process. Aiming for efficient design and construction project management an integrated analysis of the process stages is needed. The contribution of project, organizational and external environment factors should also be taken into account. The investigated problem is assigned to an increasing the efficiency of construction project management via employing the multiple criteria decision support methods and information technologies.

The aim of the dissertation is the evaluation and enhancement of the effectiveness of construction project management by employing the created Model for Integrated Project Management. This model is used to develop the Construction Project Management Multiple Criteria Decision Support System based on the complex systems theory and methods of multiple criteria analysis and multi alternative design.

The thesis consists of an introduction, three chapters, conclusions and suggestions, and the list of references.

The first Chapter introduces the current situation and achievements in construction management, approaches and systems in construction, valuation criteria and modeling principles of the process.

The second Chapter is assigned to analysis of marketing systems, efficiency values and the developed model for integrated project management.

The third Chapter presents description of decision support system elements, including explicit description for creating valuation components of the system. The proposed method is realized via solution of an actual problem.

The main statements of the dissertation were discussed at nine international research conferences. The material presented in the dissertation was published in six scientific articles: two articles in the Thomson ISI Web of Science register, four articles in the EBSCO and ICONDA registers.

Reziumė

Disertacijoje nagrinėjamos statybos projekto valdymas, jame dalyvaujančios ir savo tikslus siekiančios įgyvendinti suinteresuotos grupės bei valdymą veikianti išorinė makro- ir mikroaplinka. Norint sukurti ir pasiekti efektyvų statybos projektų valdymą, reikia atlikti kompleksinę jo etapų analizę. Be to, reikia atsižvelgti į projekto, organizacinės ir išorinės aplinkos veiksnių poveikį. Nagrinėjamas statybos projektų valdymo efektyvumo didinimas, panaudojant daugiakriterinės analizės sprendimų paramos metodus ir informacines technologijas.

Darbo tikslas – įvertinti ir pagerinti statybos projektų valdymo efektyvumą, naudojant sukurtą Integruoto projektų valdymo modelį. Naudojant šį modelį buvo sukurta Daugiakriterinė statybos projektų valdymo sprendimų paramos sistema, pagrįsta sudėtingų sistemų teorija ir daugiakriterinės analizės bei variantinio projektavimo metodais.

Darbą sudaro įvadas, trys skyriai, išvados ir pasiūlymai, literatūros sąrašas.

Pirmame skyriuje apžvelgiama esama situacija ir pasiekimai projekto valdymo srityje, valdymo metodai ir sistemos, vertinimo kriterijai ir valdymo proceso modeliavimo principai.

Antrame skyriuje analizuojamos marketingo sistemos, efektyvumo parametrai ir aprašomas sukurtas Integruoto projektų valdymo modelis.

Trečiame skyriuje aprašomi sprendimų paramos sistemos elementai, plačiai aprašomi sistemos vertinimo komponentų sukūrimas. Pasiūlytasis metodas iliustruotas aprašant aktualaus praktikoje uždavinio sprendimą.

Pagrindiniai darbo teiginiai buvo aptarti devyniose tarptautinėse ir nacionalinėse konferencijose ir seminaruose. Darbo rezultatai buvo publikuoti šešiuose moksliniuose straipsniuose, iš jų dviejuose žurnaluose, įtrauktuose į Thomson ISI duomenų bazę, keturiuose – EBSCO ir ICONDA duomenų bazėse.

Contents

INTRODUCTION 1
The Investigated Problem 1
Importance of the Thesis 1
The Object of Research 2
The Goal of the Thesis 2
The Tasks of the Thesis 2
Research Methodology 3
Importance of Scientific Novelty 3
Practical Significance of Achieved Results 4
The Defended Statements 4
Approval of the Results 5
Dissertation Structure 5

1.THE ANALYSIS OF UP-TO-DATE RESEARCH FOR CONSTRUCTION PROJECT MANAGEMENT 7
1.1. Integrated Construction Project Management 7
1.2. Artificial Intelligence Approaches and Systems in Construction 12
1.3. Methods of Multiple Criteria Analysis of Integrated Construction Management 16
1.4. Determination of a Set of Criteria Pertaining to Construction ProjectManagement 18
1.5. Establishment of Interested Parties 23

1.6. Modeling of Construction Project Management 26
1.7. Concluding Remarks of Chapter 1 30

2. MODEL FOR INTEGRATED PROJECT MANAGEMENT 31
2.1. Introduction to an Integrated Project Management 31
2.2. Knowledge Management Models and Theories 33
2.3. Model for an Integrated Project Management 36
2.4. The Effect of Changing the External Efficiency Level Factors on the Efficiency of Integrated Construction Management 39
2.5. Operation and Development of Electronic Markets as Prognostic Instrument for Business Planning 41
2.5.1. Introduction to Electronic Markets 41
2.5.2. The Delphi Method as an Established Prognostic Instrument 42
2.5.3. The Further Development to an Electronic-Based Prognostic Instrument 43
2.5.4. The Recipe for Success of the Electronic Markets 43
2.5.5. The Function of the Prediction Markets 45
2.5.6. Outline Conditions for the Gain of Information by Prediction Markets . 45
2.5.7. Future Possible Uses of Prediction Markets 46
2.6. The Development of an Electronic System for Contracts and the Execution of Construction Work in Germany 48
2.6.1. Introduction to Electronic System for Contracts 48
2.6.2. Electronic Contracts for the Execution of Construction Work 50
2.6.3. Projects for the Implementation of the Electronic System for Contracts and the Execution of Construction Work in Germany 53
2.7. The Effect of Changing the Project and Organizational Efficiency Level Factors on the Efficiency of Integrated Construction Management 62
2.8. Post-Mortem Analysis on the Analysis and Evaluation of Risks in Construction Project Management 66
2.8.1. Introduction to Risk and Post-Mortem Analysis 66
2.8.2. Risk Management in Projects 67
2.8.3. The Post-Mortem Analysis as a Tool for the Identification and Evaluation of Project Risks 68
2.8.4. Use of the Post-Mortem Analysis in the Risk Management of Construction Projects 72
2.9. Risks Management in Construction Project Management 76
2.9.1. Introduction to Risk Management 76
2.9.2. Definition of Risk 77
2.9.3. Risk Management 77
2.9.4. Risk Management in the Progress of the Project 83
2.10. Strategies for Avoiding Asymmetric Information in Construction Project Management 88
2.10.1. Introduction to Strategies of Information 88
2.10.2. Basic Principles 88
2.10.3. Importance of Asymmetrical Information in Construction Project Management 91

2.11. Performance of Transformational Learning and Redesigning the Manager' Mental and Practical Behavior 95
2.12. Concluding Remarks of Chapter 2 99

3. CONSTRUCTION PROJECT MANAGEMENT MULTIPLE CRITERIA DECISION SUPPORT SYSTEM 101
3.1. Complex Systems Theory and Multi-Criteria Decision Making 101
3.2. A Construction Project Management Multiple Criteria Decision Support System 103
3.3. Case Study: Construction Project Management 108
3.4. Manual Calculations 120
3.4. Concluding Remarks of Chapter 3 125

GENERAL CONCLUSIONS 127

REFERENCES 129

LIST OF PUBLICATIONS BY THE AUTHOR ON THE TOPIC OF THE DISSERTATION IN THE REVIEWED SCIENTIFIC JOURNALS 139

Turinys

ĮVADAS 1
Tiriamoji problema 1
Darbo aktualumas 1
Tyrimų objektas 2
Darbo tikslas 2
Darbo uždaviniai 2
Tyrimų metodika 3
Darbo mokslinis naujumas 3
Darbo rezultatų praktinė reikšmė 4
Ginamieji teiginiai 4
Darbo rezultatų aprobavimas 5
Disertacijos struktūra 5

1. NAUJAUSIŲ MOKSLINIŲ TYRIMŲ STATYBOS PROJEKTŲ VADYBOS SRITYJE ANALIZĖ 7
1.1. Integruotoji statybos projektų vadyba 7
1.2. Dirbtinio intelekto metodai ir sistemos statyboje 12
1.3. Integruotosios statybos projektų vadybos daugiakriterinės analizės metodai 16
1.4. Statybos projektų vadybos kriterijų aibės nustatymas 18
1.5. Suinteresuotųjų šalių nustatymas 23
1.6. Statybos projektų vadybos modeliavimas 26
1.7. Pirmojo skyriaus išvados 30

2. INTEGRUOTOSIOS STATYBOS PROJEKTŲ VADYBOS MODELIS 31
2.1. Įvadas į integruotąją statybos projektų vadybą 31
2.2. Žinių vadybos modeliai ir teorija 33
2.3. Integruotosios projektų vadybos modelis 36
2.4. Išorinių poveikio veiksnių efektyvumo lygio pakeitimo poveikis integruotajam statybos vadybos efektyvumui 39
2.5. Elektroninių rinkų funkcionavimas ir plėtra kaip prognostinės priemonės verslui planuoti 41
2.5.1. Įvadas į elektronines rinkas 41
2.5.2. Delphi metodas, kaip prognostinių priemonių nustatymo priemonė 42
2.5.3. Elektroniniais metodais grįstų priemonių tolimesnė plėtra 43
2.5.4. Elektroninių rinkų sėkmės receptai 43
2.5.5. Rinkos prognozavimo funkcija 45
2.5.6. Pagrindinės sąlygos pelnui iš rinkų prognozavimo informacijos gauti .. 45
2.5.7. Rinkos prognozės taikymo galimybės ateityje 46
2.6. Elektroninės sutarčių ir statybos darbų vykdymo elektroninės sistemos plėtra Vokietijoje 48
2.6.1. Įvadas į sutarčių elektronines sistemas 48
2.6.2. Elektroninės statybos darbų vykdymo sutartys 49
2.6.3. Elektroninių sutarčių ir statybos darbų vykdymo sistemų projektai Vokietijoje 53
2.7. Projekto ir organizacinių našumo lygio veiksnių pokyčio poveikis integruotajam statybos vadybos efektyvumui 62
2.8. Statybos projektų vadybos „post-mortem“ analizė ir rizikos įvertinimas 65
2.8.1. Įvadas į rizikos ir „post-mortem“ analizę 65
2.8.2. Projektų rizikos vadyba 66
2.8.3. „Post-mortem“ analizė kaip priemonė nustatyti ir vertinti projekto riziką 67
2.8.4. „Post-mortem“ analizės taikymas statybos projektų rizikai valdyti 72
2.9. Statybos projektų vadybos rizikos vadyba 76
2.9.1. Įvadas į rizikos vadybą 76
2.9.2. Rizikos apibrėžimas 77
2.9.3. Rizikos vadyba 77
2.9.4. Rizikos vadyba projekto vykdymo eigoje 83
2.10. Strategijos skirtos statybos projektų vadybos asimetrinei informacijai išvengti . 87
2.10.1. Įvadas į informacijos strategijas 87
2.10.2. Pagrindiniai principai 88
2.10.3. Nesimetrinė informacijos reikšmė statybos projektų vadybai 91
2.11. Persitvarkymo mokymosi ir vadybininko psichologijos ir elgesio pertvarkos nauda 94
2.12. Antrojo skyriaus išvados 98

3. DAUGIAKRITERINĖ STATYBOS PROJEKTŲ VADYBOS SPRENDIMŲ PARAMOS SISTEMA 101
3.1. Sudėtingų sistemų teorija ir daugiakriterinis sprendimų priėmimas 101

3.2. Statybos projektų vadybos daugiakriterinė sprendimų paramos sistema 103
3.3. Tiriamasis pavyzdys: statybos projektų vadyba 108
3.4. Rankiniai skaičiavimai 120
3.5. Trečiojo skyriaus išvados 125

BENDROSIOS IŠVADOS 127

LITERATŪRA IR ŠALTINIAI 129

AUTORIAUS PUBLIKACIJOS DISERTACIJOS TEMA 139

Introduction

The Investigated Problem

Aiming for efficient design and construction project management an integrated analysis of the process stages is needed. The contribution of project, organizational and external environment factors should also be taken into account. The investigated problem is assigned to an increasing the efficiency of construction project management via employing the multiple criteria decision support methods and information technologies.

Importance of the Thesis

The level of the efficiency of construction project management depends on a number of variables distributed in three levels, namely: project, organizational and external ones. Thus, the efficiency of construction project management depends on the aggregate effect of factors of above listed levels. The problem is how to define an efficient construction project management when the alternative project versions achieve the number of hundreds thousand and the efficiency changes with the alterations in the project, organizational and external environment conditions and the constituent parts of the process. Moreover, the

realization of some objectives seems to be more rational from the economic perspective thought, while they have the various significances when considering the other perspectives. Finally, it is stated that the efficiency of a construction project management depends on the rationality of its stages as well as the rational character of environmental conditions.

The Object of Research

The level of the efficiency of construction project management depends on a number of variables distributed in three levels, namely: project, organizational and external ones. Thus, the efficiency of construction project management depends on the aggregate effect of factors of above listed levels. The problem is how to define an efficient construction project management when the alternative project versions achieve the number of hundreds thousand and the efficiency changes with the alterations in the project, organizational and external environment conditions and the constituent parts of the process. Moreover, the realization of some objectives seems to be more rational from the economic perspective thought, while they have the various significances when considering the other perspectives. Finally, it is stated that the efficiency of a construction project management depends on the rationality of its stages as well as the rational character of environmental conditions.

The Goal of the Thesis

The aim of the dissertation is the evaluation and enhancement of the effectiveness of construction project management by employing the created Model for Integrated Project Management. This model is used to develop the Construction Project Management Multiple Criteria Decision Support System based on the complex systems theory and methods of multiple criteria analysis and multi alternative design.

The Tasks of the Thesis

Aiming to reach the aim, the following objectives are set:

1. To analyze research made by investigators of various countries in the field of current investigation.
2. To identify and describe the major worldwide construction project management trends and provide subsequent recommendations.

3. To develop a Model for Integrated Project Management based on the complex systems theory.
4. To verify the Model for the Integrated Project Management in the operational conditions.
5. To suggest the systems and subsystems of criteria related to the construction project management.
6. To adapt methods for performing multivariant design and multiple criteria analysis of the alternatives for the construction project management.
7. To show how changes in the project, organizational and external environment influence changes in the value and utility degree of the construction project management.
8. To develop the Multiple Criteria Decision Support System of Construction Project based on the complex systems theory and the developed Model.
9. To develop the complex databases of a construction project management and its stages.

Research Methodology

The research methodology is based on the analysis of worldwide publications in this field. The thesis is based on the analysis of worldwide research and other publications, encyclopedia directories, specialized dictionaries, statistical publications, statistical data of various countries on the internet, other scientific and informational publications of different research institutions. The Methods for processing data of project multi-criteria analysis, created by Zavadskas and Kaklauskas (Kaklauskas *et al*. 2005), and complex systems theory were applied to the researches that were made.

Importance of Scientific Novelty

1. An original Model for an integrated project management enabling the user to analyze a construction project management and its separate parts as well as the whole one, which of the organizational and external environment is developed.
2. The suggested systems and subsystems of criteria relating to a construction project management and based on economic, technical, technological, managerial, qualitative, legislative, social and other factors are developed.

3. Methods for performing multi- analysis of global research shows that the existing intelligent systems do not perform the multi-variant design of construction project management alternatives.
4. Methods for performing multivariant design and multiple criteria analysis of the alternatives developed by E. K. Zavadskas and A. Kaklauskas and the theory of complex systems have been adapted for the construction project management.
5. A formalized presentation of the research shows how the changes in the project, organizational and external environment influence the changes in the value and utility degree of the construction project management.
6. The Construction Project Management Multiple Criteria Decision Support System was developed based on the complex systems theory and Model.
7. Complex databases of a construction project management and its stages have been developed.

Practical Significance of Achieved Results

The achieved research results can be used for efficient decision-making in construction project management via employing the developed Model for Integrated Project Management. The results have been used in WSP CBP Consulting Engineers AG, Germany.

The Defended Statements

1. The developed Model for Integrated Project Management allows describing adequately the construction project management, that of the stakeholder groups and organizational and external environment influence the project process. The model allows valuation the above factors as an integral system for making an efficient decision.
2. The developed integrated construction project management database allows describing construction project management and surrounding project, organizational and external environment accurately.
3. The adapted complex systems theory, multi-variant design and multi-criteria analysis methods were improved and adjusted to the developed Model for an Integrated Project Management; they allow automating composition of numerous alternatives and making integrated evaluation of their economic, technical, qualitative, technological, organizational, managerial, legal and other aspects, as well as making a decision.

4. The developed Multiple Criteria Decision Support System of Construction Project Management and its testing in practice confirmed the efficiency of the developed model, that of the methods and that of the system.

Approval of the Results

The material presented in the thesis was published in six scientific articles. The main statements of the dissertation were discussed at nine international and national scientific conferences and seminars:

- The International Conference on Business and Management, held in Vilnius, 2008;
- The 9-th International Conference "Modern Building Materials, Structures and Techniques, held in Vilnius, 2007;
- The Munich Symposium of Civil Engineering, held in Munich, 2005;
- The Seminar on Management in Construction, held in Augsburg, 2001;
- The VHK-Forum "Bau" – 98 Bayern, held in Munich, 1998;
- The VHK-Forum "Bau" – 97 Bayern, held in Munich, 1997;
- The VHK-Forum "Bau" – 96 Bayern, held in Munich, 1996;
- The VBI Seminar, held in Munich, 1995;
- The VDI Congress, held in Hanover, 1992.

Dissertation Structure

The dissertation consists of an introduction, three chapters, conclusions and suggestions, and the list of references.

The total scope of dissertation is 135 pages, 6 expressions, 11 figures, 1 table and 145 references.

1

The Analysis of Up-to-date Research for Construction Project Management

1.1. Integrated Construction Project Management

The definitions of project management (PM) and construction management can be found in different literature sources as follows:

- The delivery and management of projects – it is usually performed by Program Management specialists (Ancarani, Capaldo 2005).
- Project management – application of the knowledge, skills, tools and techniques during the project activities in order to meet or surpass the needs and expectations of all the participants interested in the project results (Anderson, McNeil 2005).
- The methods and disciplines used to define goals, plan and monitor tasks and resources, identify and resolve issues, and control costs and budgets for a specific project (Baldwin *et al*. 2008).
- PM is a business process of the project-oriented company. The PM process starts with the project assignment and ends with the project approval. It consists of the sub-processes project start, project coordination, project

controlling, project discontinuity management and project close-down (Ballestín *et al*. 2009).

- Project management is the process by which projects are defined, planned, monitored, controlled and delivered such that the agreed benefits are realized. Projects are unique, transient endeavors undertaken to achieve a desired outcome (Brown *et al*. 2007).
- PM is a critical skill required for execution. It is an essential organizing and managerial discipline in getting things done (Baiden *et al*. 2006).
- The techniques & tools used to describe, control & deliver a series of activities with given deliverables, timeframes & budgets (eTraiding Partners 2009).
- Planning, monitoring and control of all aspects of a project and the motivation of all those involved in it to achieve the project objectives on time and to the specified cost, quality and performance (Alternative definition – The controlled implementation of defined change) (Cameron 2005).
- A management philosophy that says that efficient management will yield effective results. Specifically, efficient management of resources and constraints to perform tasks in order to achieve a desired result (Foran *et al*. 2005).
- Support of initiatives through the provision of project management (Twort and Rees 2004).
- The leadership role which plans, budgets, co-ordinates, monitors and controls the operational contributions of property professionals, and others, in a project involving the development of land in accordance with a client's objectives in terms of quality, cost and time (Caldas, Soibelman 2003).
- Project Management is a formalized and structured method of managing change in a rigorous manner. It focuses on achieving specifically defined outputs that are to be achieved by a certain time, to a defined quality and with a given level of resources so that planned outcomes are achieved (Cheng *et al*. 2009a).
- A professional management practice consisting of an array of services applied to construction projects and programs through the planning, design, construction and post construction phases for the purpose of achieving project objectives including the management of quality, cost, time and scope (Chen and Chen 2009).
- Organizing and directing men, materials, and equipment to accomplish the purpose of the designer (Cheng *et al*. 2009a).

- Where a contractor is engaged to manage the construction of a project for an agreed fee and the trade contractors are engaged either directly by the client or an open book analysis (Lin and Hsieh 2004).
- Construction supervision by a qualified manager (Chrisp *et al*. 2003).

A construction project manager is a professional in the field of construction project management. Project managers are responsible for planning, execution, and closing of construction project. A project manager is the person accountable for accomplishing the stated construction objectives. Key project management responsibilities include creating clear and attainable construction objectives, building the project requirements, and managing the triple constraint for projects, which is cost, time, and scope (Wikipedia 2009f).

Project management is quite often the province and responsibility of an individual project manager. This individual seldom participates directly in the activities that produce the building, but rather strives to maintain the progress and mutual interaction and tasks of various parties in such a way that reduces the risk of overall failure, maximizes benefits, and restricts costs (Slideshare 2009).

The tools, knowledge and techniques for managing projects are often unique to construction management. For example: work breakdown structures, critical path analysis and earned value management. Understanding and applying the tools and techniques which are generally recognized as good practices are not sufficient alone for effective construction management. Effective construction management requires that the project manager understands and uses the knowledge and skills from at least four areas of expertise (AIPMI 2009).

When recruiting and building an effective construction team, the manager must consider not only the technical skills of each person, but also the critical roles and relationships between workers. A construction project manager is a professional in the field of construction project management. Project managers can have the responsibility of the planning, execution, and closing of construction project (Wikipedia 2009f).

Recently a different business models (design-build, owner-designer, owner-construction manager, owner-builder, etc.) has become more popular. Many owners, particularly government agencies, have let out contracts, which are known as Design-Build contracts. In this type of contract, the construction team is known as the design-builder. They are responsible for taking a concept developed by the owner, completing the detailed design, and then pending the owner's approval on the design, they can proceed with construction. Virtual Design and Construction technology has enabled much of the ability of contractors to maintain tight construction time frames (Reference.com 2009).

An alternate contract or business model replaces the two traditional contracts with three contracts: owner-designer, owner-construction manager, and

owner-builder. The construction management company becomes an additional party engaged in the project to act as an advisor to the owner, to which they are contractually tied. The construction manager's role is to provide construction advice to the designer, on the owner's behalf, design advice to the constructor, again on the owner's behalf, and other advice as necessary (Siegmann 2009).

Virtual Design and Construction (VDC) is the use of integrated multi-disciplinary performance models of design-construction projects, including the Product (i.e. facilities), Work Processes and Organization of the design-construction-operation team in order to support explicit and public business objectives. The theoretical basis of VDC includes (Open Link 2009):

- Engineering modeling methods: product, organization, process;
- Analysis methods (model-based): including schedule, cost, 4D interactions and process risks;
- Visualization methods;
- Business metrics and focus on strategic management;
- Economic Impact analysis (i.e., models of both the cost and value of capital investments).

"VDC models are virtual because they show computer-based descriptions of the project. The VDC project model emphasizes those aspects of the project that can be designed and managed, i.e., the product (typically a building or plant), the organization that will define, design, construct and operate it, and the process that the organization teams will follow, or POP. These models are logically integrated in the sense that they all can access shared data, and if a user highlights or changes an aspect of one, the integrated models can highlight or change the dependent aspects of related models. The models are multi-disciplinary in the sense that they represent the Architect, Engineering, Contractor (AEC) and Owner of the project, as well as relevant sub disciplines. The models are performance models in the sense that they predict some aspects of project performance, track many that are relevant, and can show predicted and measured performance in relationship to stated project performance objectives. Some companies now practice the first steps of VDC modeling, and they consistently find that they improve business performance by doing so." (Kunz and Fischer 2007).

There are two main advantages to using a design-build contract. First, the construction team is motivated to work with the design team to develop a design with constructability in mind. In that way it is possible for the team to creatively find ways to reduce construction costs without reducing the function of the final product. The owner can expect a reduced price due to the increased constructability of the design. The other major advantage involves the schedule. Many projects are given out with an extremely tight time frame. By letting out the contract as a design-build contract, the contractor is established, and

early mobilization and construction activities are able to proceed concurrently with the design. Under a traditional contract, construction cannot begin until after the design is finished, the project is bid and awarded, and the team can mobilize. This type of contract can take months off the finish date of a project (Kota 2009).

Construction Cost Management is a fee-based service in which the Construction Manager (CM) is responsible exclusively to the owner and acts in the owner's interests at every stage of the project. The construction manager offers advice, uncolored by any conflicting interest, on matters such as (Cordoba 2009):

- Optimum use of available funds;
- Control of the scope of the work;
- Project scheduling;
- Optimum use of design and construction firms' skills and talents;
- Avoidance of delays, changes and disputes;
- Enhancing project design and construction quality;
- Optimum flexibility in contracting and procurement;
- Cash flow Management.

Comprehensive management of every stage of the project, beginning with the original concept and project definition, yields the greatest possible benefit to owners from Construction Management. As time progresses beyond the pre-design phase the CM's ability to effect cost savings diminishes. The Agency CM can represent the owner by helping to select the design team as well as the construction team and manage the design preventing scope creep, helping the owner stay within a pre-determined budget by performing Value Engineering, Cost/Benefit Analysis and Best Value Comparisons. The Agency CM can even provide oversight services for a CM At-Risk contract (BOYD Construction 2009).

CM at-Risk is a delivery method which entails a commitment by the construction manager to deliver the project within a Guaranteed Maximum Price (GMP), in most cases. The construction manager acts as consultant to the owner in the development and design phases, (often referred to as "Preconstruction Services"), but as the equivalent of a general contractor during the construction phase. When a construction manager is bound to a GMP, the most fundamental character of the relationship is changed. In addition to acting in the owner's interest, the construction manager must manage and control construction costs to not exceed the GMP, which would be a financial hit to the CM Company (MWH 2009).

CM "At Risk" is a global term referring to a business relationship of Construction contractor, Owner and Architect / Designer. Typically, a CM at Risk arrangement eliminates a "Low Bid" construction project. A GMP agreement is

a typical part of the CM and Owner agreement somewhat comparable to a "Low Bid" contract, but with a number of adjustments in responsibilities required by the CM. Aspects of GMP agreements will be elaborated below. The following are some primary aspects of the most potential benefits of a CM At Risk arrangement: Budget management: Before design of a project is completed (6 months to 1–1/2 years of coordination between Designer and Owner), the CM is involved with estimating cost of constructing a project based on hearing from the designer and Owner (design concept) what is going/desired to be built. Upon some aspect of desired design raising the cost estimate over the budget the Owner wants to maintain, a decision can be made to modify the design concept instead of having to spend a considerable amount of time, effort and money re-designing and/or modifying completed construction documents, or, the Owner decides to spend more money or obtain higher financial support for the project. To manage the budget before design is done, construction crews are mobilized. CM is spending tens of thousands per week just having onsite management, major items are purchased, etc, is an extremely more efficient use of everyone's time, effort, Architect/Designer's costs, and the CM's General Conditions costs, AND delivering to the Owner a design within his budget (PediaView 2009).

1.2. Artificial Intelligence Approaches and Systems in Construction

The ability over the course of a construction project to make reliable predictions regarding cash flows enhances project cost management. This research uses artificial intelligence (AI) approaches to predict cash flow trends for such projects in order to develop appropriate strategies that apply factors such as float, process execution time, construction rate and resource demand to project cash flow control. AI approaches involved in this research include K-means clustering, genetic algorithm (GA), fuzzy logic (FL), and neural network (NN). K-means clustering is employed to categorize similar projects, while the other approaches are used to develop the Evolutionary Fuzzy Neural Inference Model (EFNIM), a knowledge learning model. FL and NN are employed in the EFNIM to develop a neural-fuzzy model that can deal with uncertainties and knowledge mapping. GA is used to optimize the membership functions of FL and NN parameters globally. The major target of this AI learning is to address sequential cash flow trends. This trained result is furthermore applied to a strategic project cash flow control. This cash flow control affects project performance within the banana envelope of the S-curve for project management (Cheng 2009c).

Long and Ohsato (2009) develop a new method for scheduling repetitive construction projects with several objectives such as project duration, project cost, or both of them. The method deals with constraints of precedence relationships between activities, and constraints of resource work continuity. The method considers different attributes of activities (such as activities which allow or do not allow interruptions), and different relationships between direct costs and durations for activities (such as linear, non-linear, continuous, or discrete relationship) to provide a satisfactory schedule. In order to minimize the mentioned objectives, the proposed method finds a set of suitable durations for activities by genetic algorithm, and then determines the suitable start times of these activities by a scheduling algorithm. The bridge construction example from literature is analyzed to validate the proposed method, and another example is also given to illustrate its new capability in project planning (Long and Ohsato 2009).

In complex and high value projects, prequalification is crucial for both contractors and clients, as it targets towards best value delivery through qualification safeguards and streamlined competition among potential candidates. Due to the complex nature of the procurement problems such as prequalification exercises, the robust models are rarely attempted. Lam and Ng (2006) present an overview of potential suitability of Support Vector Machine (SVM) method for contractor/consultant prequalification transactions in the construction project procurements. Furthermore, the performance of SVM is compared with specific artificial neural network outcomes. The results obtained from practical datasets indicate encouraging potentials for SVM applications in the procurement problems such as prequalification and contractor selection. Hence, a SVM-based decision support framework is proposed.

In Professional Construction Management (PCM), service performance in the design stage most affects the overall project results. However, currently it is hard to quantify the results and make a proper determination of the quality of the PCM design service because the evaluation mechanism and procedures have not been completely implemented yet. To deal with the problem, the study of Wang and Hsu (2009) investigates owners' opinions and thereby establishes the representative performance indicators of PCM design service. An effectiveness analysis method and a neural network method are successfully combined, so as to construct an evaluation approach of PCM service performance in the design stage. This approach can offer a listing of rank and level of design service performance in PCM projects, and further provides a simple appraisal table, so that the owner can effectively measure the performance of PCM design service. Finally, through the case study, this approach is verified to be reasonable and acceptable in practice. The approach can be an effective tool when measuring the PCM design service performance and can help owners to evaluate and choose PCM consultants in the design stage (Wang and Hsu 2006).

The refurbishment market has grown greatly in the last decade. Relevant projects are becoming increasingly more demanding in the construction industry due to the emphasis on sustainability. Most refurbishment works, however, involve a higher level of risk and uncertainty, as well as more complex coordination than new buildings. These characteristics are likely to cause asymmetric information between contractors and tenants in a refurbishment process and thus affect customers' satisfaction and project performance. The study of Chou (2009) proposes a systematic decision support approach to solve refurbishment asymmetric information problems by using case-based reasoning (CBR) and data envelopment analysis (DEA). The PZB model of the service quality and fuzzy sets are applied to support the DEA operation. With this intelligent approach, tenants can select an optimal refurbishment contractor according to their customization needs and contractors can find out their inefficient factors to improve their business competitiveness. The proposed hybrid decision support approach is expected to be useful for both tenants and contractors in those developed countries or regions with high refurbishment needs when they face similar problems (Chou 2009).

In construction projects, time and cost are manageable objectives with significant interdependencies for which sets of trade-offs may exist. Eshtehardian *et al.* (2009) study presents a new approach for the solution of time–cost trade off problems in an uncertain environment. Fuzzy numbers are used to address the uncertainties in the activities execution times and costs. Fuzzy sets theory is then explicitly embedded into the optimization procedure. A multi-objective genetic algorithm is specially tailored to solve the discontinuous and multi-objective fuzzy time-cost model with relatively large search space. The proposed approach identifies the best set of implementation options defined by the sets of non-dominated solutions. Accepted risk level and optimism of the decision maker are addressed using α-cut approach and optimism index (β) respectively. To illustrate the application and performance of the model, two case examples are presented, for which separate Pareto fronts are developed. The fuzzy presentation of the non-dominated solution helps the project manager to apply his own level of risk acceptance and degree of optimism in decision making process. Different risk acceptance level and/or optimism leads to different scheduling and sets of Pareto solutions from which the project manager may select his preferred options (Eshtehardian *et al*. 2009).

With low demand for new construction, limited land usage, and being aware of sustainability, the refurbishment market has grown greatly and has become more in demand in the construction industry. Most refurbishment work, however, involves a high level of risk, uncertainty, and coordination, which are likely to cause asymmetric information between contractors and residents in a refurbishment process. Most private refurbishment contractor

selections are usually based on word-of-mouth referrals that lack a systematic and objective assessment method. Juan *et al.* (2009) proposes a hybrid approach combining fuzzy set theory and quality function deployment (QFD) to establish a housing refurbishment contractor selection model. With this model, residents can select an optimal refurbishment contractor according to requirements. To test the effectiveness of the proposed model, a known multiple criteria decision-making method, PROMETHEE, is applied to compare the results of contractor selections. The result reveals that the proposed hybrid fuzzy-QFD approach can be expected to be successful and has potential for handling multiple criteria decision-making problems (Juan *et al.* 2009).

Conceptual cost estimates, the basis of project evaluation, engineering design, cost budgeting, and cost management, not only play an essential role in construction project feasibility studies, but are fundamental to a project's ultimate success. As practiced today, construction cost estimates generally rely on experts' intuitive experience. Scientific methods should be developed and employed during project planning and design stages in order to raise conceptual cost estimate accuracy. Cheng *et al.* (2009a) study proposes the use of an artificial intelligence approach, the Evolutionary Fuzzy Neural Inference Model (EFNIM), to improve cost estimation accuracy. The advantages inherent in Genetic Algorithms, Fuzzy Logic and Neural Networks are incorporated into the EFNIM, making this model highly applicable to identifying optimal solutions for complex problems (Cheng *et al.* 2009a).

Supplier selection negotiation is a sophisticated and challenged job due to the diversity of intellectual backgrounds of the negotiating parties, the many variables involved in supply–demand relationship, the complex interactions and the inadequate negotiation knowledge of project participants. To do the job well, it is necessary to develop an intelligent system for negotiation support in supplier selection process. Therefore, an artificial neural network-based predictive model with application for forecasting the supplier's bid prices in supplier selection negotiation process (SSNP) is developed in this research. By means of the model, demander can foresee the relationship between its alternative bids and corresponding supplier's next bid prices in advance. The purpose of this research is applying the model's forecast ability to provide negotiation supports or recommendations for demander in deciding the better current bid price to decrease meaningless negotiation times, reduce procurement cost, improve negotiation efficiency or shorten supplier selection lead-time in SSNP (http://portal.acm.org/citation.cfm?id=1465222), (Ching-Lee and Ou-Yang 2009).

1.3. Methods of Multiple Criteria Analysis of Integrated Construction Management

The determination of the utility degree and value of the integrated construction project management under investigation and establishment of the priority order for its implementation does not present much difficulty if the criteria numerical values and weights have been obtained and the multiple criteria decision making methods are used.

When drawing up the system of criteria that fully describes the life cycle of construction management, it is worthwhile taking into account the suggestions of other researchers. This is explained by the fact that the goals pursued by the stakeholders and the system of criteria describing the integrated construction management in a certain sense are rather subjective. Therefore, in order to increase the degree of objectivity, the authors shall rely on the suggestions of specialists working in this field, when drawing up the system of criteria describing the integrated construction management. As example, some criteria systems are presented below.

Sidwell (1983) listed several criteria which were generally used to evaluate a project. These include time, cost, aesthetics, function, quality, client's satisfaction and team members' relation. Pinto and Slevin (1988) also argued that the triple constraints approach toward project evaluation is too simplistic. They highlighted customer satisfaction as an important criterion for project evaluation, in line with Sidwell's (1983) evaluation method.

Freeman and Beale (1992) identified seven main criteria used to measure project success. Five of the frequently used criteria were the technical performance, efficiency of execution, managerial and organizational implications, personal growth and manufacturer's ability and business performance. Freeman and Beale (1992) mentioned that it is necessary to understand the two components of project success in order to measure success, which may comprise project management success, or product success, or both. Project management success measured in terms of cost, time and quality can be viewed as internal measures of efficiency while product success is concerned with the project's external effectiveness (Pheng and Chuan 2006).

Contractor pre-qualification is characterized as a multi-criteria problem with uncertain inputs. The criteria used for contractor pre-qualification include qualitative and quantitative information. Owing to the nature of pre-qualification, which depends on subjective judgments of construction professionals, it becomes an art rather than a science. Further, there is an inherent non-linear relationship between the input and the output of contractor's pre-qualification models (El-Sawalhi *et al.* 2007).

One of the most important elements in construction procurement is the contractor selection, which can result from contractor's ranking. Contractor prequalification is essential in most construction projects, and the process has been performed by many different methods in practice. In most studies of contractor selection, selection criteria are assumed to be independent of each other. However, these criteria are likely to affect each other (Darvish *et al.* 2009).

Risk management is used more and more in building industry projects. An essential element of the risk management process is the analysis and evaluation of risks. Therefore, project assessment with the help of the post-mortem analysis plays an important role. The post-mortem analysis is a tool frequently used in software projects today for the reduction of risks. The clearness of the goal of improvement measures is sharpened by the examination of the project steps in connection with the success factors of the organization. The results of a post-mortem analysis deliver detailed information on where improvement measurements are necessary in the project future. Growth in project management know-how is created through the discussion of the participants of all hierarchy levels. Therefore, the post-mortem analysis is also applicable for use in the construction project. The procedure is introduced in the work at hand (Schieg 2007).

By adopting risk management, savings potentials can be realized in construction projects. For this reason, for project managers as well as real estate developers, a consideration of the risk management process is worthwhile. The risk management process comprises 6 process steps, which will be discussed in greater detail below. The integration of a risk management system in construction projects must be oriented to the progress of the project and permeate all areas, functions and processes of the project. In this, particular importance is attached to the risks in the personnel area, for, particularly for enterprises providing highly qualified services, specialized employees are essential for market success (Schieg 2006a, 2006b).

The multiple criteria decision making area has a large set of tools the purpose of which is to help the decision-maker solve a decision problem by taking into account several, often contradictory, points of view. In general, multiple criteria decision making methods are divided into three large families (Vincke 1992): unique synthesis criterion, consisting of aggregating different points of view into a unique function which must subsequently be optimized; the outranking synthesis approach, using methods which aim first to build a relation, called an outranking relation, which represents the decision-maker's strongly established preferences, given the information at hand; and the interactive local judgment approach, proposing methods which alternate calculation and dialogue steps.

Mota *et al.* (2009) present a model for supporting project managers to focus on the main tasks of a project network using a multiple criteria decision aid (MCDA) approach.

The researchers from various countries engaged in the analysis of construction management life cycle and its stages did not consider the research object being analyzed by the authors of the present investigation. The latter may be described as follows: a life cycle of a construction management as well as project, organizational and external environment having a particular impact on it making an integral whole. To investigate the research object defined in the present research complex systems theory and some methods of multiple criteria analysis were applied.

1.4. Determination of a Set of Criteria Pertaining to Construction Project Management

One of the most effective ways to identify highly productive construction firms, procurers, etc. is to hold competitions for the contract. The procedure is discussed by the author from the client's point of view in order to show his attitude towards the construction firms. Basically the competitions are organized according to the only criterion that is price. But the client also displays his interests in other characteristics such as the quality of the finished building products, duration of construction, etc. in which there is also no limit for improvement. The reputation of the construction firm as well as its financial power trustfulness and are of great importance. They guarantee that the contractors will not go bankrupt and all the terms of the contract will be fulfilled. From this example it is seen that the competitions for a certain contract should be organized taking into account the whole system of criteria, fully reflecting the objectives to be reached. It is quite natural, that the construction companies like all the parties involved into a project also seek to attain some economic or other advantages.

Pati *et al.* (2009) treats rational expressions of building performance in order to better support dialogues between stakeholders. These expressions are based on the notion of objectively quantifiable performance measures, which are introduced through a set of “performance indicators”. The indicators can be used to quantify expectations and fulfillments in structured dialogues between different stakeholders. The focus of the research is on the introduction of two types of indicators:

- Based on normative models in biophysics and physiology;
- Based on empiricist models of Environment–Behavior studies.

The treatment is positioned to support rational decision making during different stages of building delivery and use. The focus of this research is specifically on informing decisions during design evolution, and facility and portfolio management phases of a building's lifecycle.

Several planning, engineering, management, and operational tasks are candidates for expert-system formulation (Mohan 1990):

- Constructability evaluation-some important issues include analysis of the constructability of designs, choice of construction materials, selection of the best design-function-cost combination, bid packaging, choice between prefabricated and in-situ construction, and feedback into the design process;
- Project management-several kinds of expert systems that could be built in this area include choice of a project-delivery strategy, selection of a contract type, design checking and management of design changes, construction-contract formulation, project-financing options, A/E and CM selection, prequalification of contractors, bidding strategies, bid evaluation, evaluating progress payments, evaluating claims, management of risks, evaluating the quality of a constructed component or facility, formulation of general conditions, and formulation of technical specifications, etc.
- The recent efforts on constructability by the Construction Industry Institute, through its Constructability Task Force, provide valuable guidance on how the management of projects can be improved (Constructability 1990):
- A constructability program is an integrated, systematic, disciplined effort to achieve the project objectives;
- To achieve maximum benefits, the constructability effort must start at the earliest planning and conceptual stages of the project;
- Experienced construction personnel must be full-fledged members of the project team to provide the balance that will optimize the various elements of the project in meeting the project's overall objectives, etc.
- The challenge in having an effective constructability program is the need to integrate engineering and construction efforts so that the professional skills and experience of both have the forum and procedures that allow them to optimize the planning, design, procurement, construction, and start-up phases of a project as an integrated whole (Constructability 1987).

Constructability can be described as:

- Project management technique to review the construction processes from start to finish during pre-construction phrase (Scott-Young and Samson 2008).

- The ability to construct under conditions available (HSI 2009).
- Members of a construction management (CM) firm need to recognize that an owner who would employ their services is going to look for these same kinds of services. The CM firm should have a program that considers, in a systematic way; all the elements and factors enumerated and are prepared to apply them to future projects (Guidelines... 1987).
- A general contractor, in applying these constructability concepts, obviously has to tailor his program to fit his scope of responsibilities within a particular project. If he is brought on board early in the planning to help the owner, most of these constructability concepts apply (Guidelines... 1987).

Constructability optimizes the following major project elements from start to finish of the project (Constructability 1990):

- Overall project plan;
- Planning and design;
- Construction-driven schedule;
- Costs or estimates;
- Construction and major construction methods.

Factors to be considered in a constructability program include the following (Constructability 1990):

- Managing the project;
- Project delivery system;
- Contracting strategy;
- Risk management;
- Work package breakdown;
- Labor plan;
- Access to site: size of equipment, weather restraints and urban restrictions;
- Site layout;
- Access to install and replace large equipment within the structure;
- Sequence of construction;
- Rigging plan;
- Availability and procurement of long lead time equipment and materials;
- Prefabrication;
- Preassembly;
- Modularization;
- Construction management organization plan;
- Quality management; materials management;
- Site facilities (offices, temporary power, water, sewer, security, roads, parking, lay down, etc.);

- Safety;
- Operability;
- Maintainability.

Further it should be discussed three earlier mentioned criteria: contracting strategy, construction and risk management.

The choice of the most appropriate contracts form for any particular project depends on a variety of factors, such as the time available before the building must be completed and ready for occupation, the time available for the preparation of tender documents, the detailed knowledge of the scope of the work and employers' requirements at the outset, the possibility of variations being required to be incorporated during the progress of the work, and the possibility of having consultants and specialist sub-contractors chosen and appointed by the employer before the main contract is let. All must be considered and given their respective priorities before the decision as to the type of contract to be used is made (Constructability 1987).

The factors that affect selection of the type of contract include the following (Constructability 1990):

- Owner's corporate policy on contracting;
- Availability of in-house experienced personnel;
- Time available to get the project designed and constructed;
- Desire of owner to control elements of project;
- Importance of cost to owner;
- Amount of risk owner wants to contract out;
- Availability of contractors;
- Local construction climate;
- Experience or confidence in contractor or design builder;
- Pre-contract period (long, short);
- Consultants (chosen by contractor or employer);
- Sub-contractors (domestic, nominated);
- Valuations of variations (expensive, cheap, at cost);
- Completion (fixed, controlled, at large).

The competitions for the actual contract should be organized taking into account a set of criteria, reflecting the objectives to be attained (Constructability 1990):

- Estimated cost of project;
- Quality of final building product;
- Duration of construction;
- Financial strength of building firm;
- Reliability of building firm;
- Organization and management capabilities;

- Ability to formulate practical programs;
- Ability to maintain program;
- Standard of workmanship;
- Site organization;
- Conduct of labor relations;
- Relations with sub-contractors and statutory authorities;
- Attention to site welfare and safety,
- Degree of co-operation;
- Appropriateness of organizational structure;
- Effectiveness of communication;
- Flexibility of management;
- Motivation of the team;
- Experience of the team;
- Did rely extensively on sub-contractors?
- Were there any problems with payments to sub-contractors and suppliers?
- Were defects remedied promptly?
- Were final accounts settled satisfactory?

The factors, representing major objectives of a construction firm, are divided into four hierarchical groups:

- Job related (type, owner, profitability, location, size, degree of hazard);
- Market related (need for work, strength of firm);
- Firm related (economic condition, competition);
- Resource related (supervisory personnel, estimators, subcontractors) (Ahmad 1990).

The lower-level criteria, or sub criteria, as determined from the results of the questionnaire survey, are grouped under each of these categories. This hierarchy of objectives implies that attainment of a lower-level objective contributes to the overall attainment of the higher-level objective, to which the lower-level objective belongs (Ahmad 1990).

The strength of the decision depends on the degrees of attainment of these objectives. The degrees are measured in terms of worth (or score) attached to each of the lower-level factors that represent the objectives (Ahmad 1990).

The construction manager, either the owner, a CM firm, or the general contractor, during the construction phase has to develop a plan to control site-related facilities and operations to facilitate constructability. Included are such things as site facilities (offices, temporary power, water, sewer, security, roads, parking, etc.); a labor plan, materials management, a rigging plan, a construction management organization plan, safety, and an intra-plant access plan to move people, materials, and equipment around the site. Major construction

methods to be employed have to be identified early, since they may determine how the project must be designed. These methods include the use of construction equipment, labor, effect of weather, and work sequencing (Constructability 1987).

On the basis of such rational constructability program the maximum benefits can be achieved. For example, business Roundtable report (Constructability 1987) estimates that constructability improvements saved at least 10–20 times the cost of the constructability effort. Specific projects have reported 6-10% savings of construction costs (Constructability 1986).

1.5. Establishment of Interested Parties

One of the major problems for enhancement of efficiency of the construction project management is establishment of rational interested parties. Each party concerned estimate the increase of efficiency as the ratio of their effort put into the project and real gain obtained in realization of it (factors of risk, the amount of received pay, how and to which degree the other demands were satisfied, etc.). In other words, the efficiency enhanced by the efforts of each party is directly proportional to the reached aims and satisfied needs. There prevails a concept that the interested parties consider the “pie under division” (the final benefit brought about by the project, received pay for work) as a fixed quantity. The stakeholders intending to boost the “pie under division” use effort to enhance efficiency of the project. So the division of the “pie” (including its increase in amount) may be treated as a positive problem as it helps the development of a more efficient organization of the parties. Everybody related to the project that is all those who by their shares contribute towards the project and get a profit from it are considered as “interested parties”. The received “pie” may be both material and immaterial (Bejder 1991).

In project management it is commonly accepted that the interests of stakeholders need to be dealt with to support the success of a project. The analysis of literature shows that only a minority of the publications provides a clear definition and addresses the identification of stakeholders. After comparing the stakeholder approach with project role classifications from the literature, we conclude that a role-based stakeholder identification method is a promising approach for identifying stakeholders in projects (Achterkamp and Vos 2007).

The interested parties can be depicted from various points of view:

- Temporary or permanent;
- The major sphere of activity (the whole of needs) of the stakeholder;
- The right time for the stakeholders to join the process being under way;

- The efforts contributed by the stakeholders towards the project and received "pie" are monetary quantities (yes/no);
- The extent of influence of the interested parties upon the project (Bejder 1991).

It is not often when in setting up a project all stakeholders are formed from the first attempt. Besides, it is characteristic that the interested parties get involved into the project in a process of its implementation. Despite of this, it is very important that those parties which exercise a great influence upon the project or are highly dependent upon it be identified as early as possible (Bejder 1991).

A negative attitude to a construction project by stakeholders can severely obstruct its implementation. Such obstruction will cause cost overruns and exceeded time schedules due to conflicts and controversies concerning project design and implementation. Method of stakeholder mapping, together with the power/interest matrix, has been used to identify stakeholders and their influence on the projects. Which problems arose, how were they resolved, and what were the consequences of the solution? Evaluation of stakeholder demands and influence should be considered as a necessary and important step in the planning, implementation, and completion of any construction project (Olander and Landin 2005).

Project managers should undertake stakeholder analysis even though it is difficult. However, doing a thorough stakeholder analysis is a time-consuming activity. Therefore, the project manager can easily be torn in a dilemma between spending time doing a thorough analysis and the need for the project to get in motion. Accordingly, project managers, at least to some extent, will have to rely on intuition and superficial analysis. To solve this problem, and keep costs in time and money at a reasonable level, the project manager should carefully consider which stakeholders are sufficiently important to warrant information gathering concerning expectations as regards rewards for delivering the needed contributions. The project manager should also make only a detailed outline for the stakeholders that are important in the early stages of the process and postpone making outlines for additional stakeholders to the moment when they become important during the project course. Project manager should see the analysis not only as resource demanding activity, but as an ongoing learning process and an opportunity to engage in dialogue with the stakeholders to take their thoughts regarding the project into consideration at an early stage. By choosing this perspective on stakeholder management stakeholder analysis can make a great contribution to the success of a project (Jepsen and Eskerod 2008).

The interested groups can often be split into smaller constituent parts. For example, a contractor consists of a great number of interested groups (managers, boss, stockholders, employees, craftsmen, workers, labor unions, etc.) whose

interests and goals may diverge from one another on many questions. The chief manager of a construction site is responsible for efficient organization of a construction process and its control which is conditioned by the right choice of subcontractors, procurers, construction methods, technologies, labor teams the members of which are supposed to work together, machinery, mechanisms, tools, etc. As every member of the contractor in addition to his professional qualities still possesses a great number of individual features (ability, ambition, skill, cooperation, aggressiveness, loyalty, trust, honor, tolerance, prejudice, obedience, compassion, conformity, etc.), his strivings not always coincide with the aims pursued by a contractor. To some extent this can have a negative effect on efficiency of the lifetime process of a project from the starting point. To prevent the possible future harm, the interested groups should be matched well with close regard of their interests. This allows achieving the maximum of efficiency.

The stakeholders are identified and grouped according to the performed functions. They are chosen in a rational way by regular intervals throughout the whole project management process.

Brain storming (the way for solving particular problems when everybody takes part in the discussion without any restrictions) is the right method for foreseeing the stakeholders and their selection 'Snow cards' is one of the ways of employment of this method. A 'snow card' s a small piece of research on which the interviewed person writes down only one interested group and points out reasons why the side in question n his view might be considered as rational one. The interviewed person fills in as many “snow cards” as he finds it necessary. The method of 'snow card' can be applied in mass gatherings (attended by hundreds of people) where groups consisting of 3 to 6 (people) work together making the cards. Later on, the authorities of a project can proceed with estimating the collected material, classifying cards into certain groups according to performed functions. The selection of rational interested groups is conducted according specially for this purpose developed criteria system (Bejder 1991).

The presented example illustrates the case of establishment of interested groups. Suppose we have to build a bridge across the river. We can readily establish that the bridge owner, the designer, contractors, users of the bridge, people living nearby, all those who go sailing under the bridge are the stakeholders. But how about the fish swimming around in the area of the bridge? There might be a spawning zone there. How is then if materials for construction (sand and stones) find themselves in the other place where there is another fish spawning area or where there is one of the best fishing areas? How is it possible to establish such stakeholders in the early stage of a project when it is still within the control, and corrections can be made (Bejder 1991)?

There are quite a lot of such points where the interests of groups concerned come into a clash. For example:

- Combining interests of a contractor with the interests of society at large;
- Surroundings of the site (before and after the construction, inside and outside);
- Durability/reliability;
- Factors of risk (technical/financial/political);
- Application;
- Duration of construction;
- The construction methods employed;
- The cost of a project, etc.

Each of the above points of a project can be estimated in various aspects.

The needs of the interested parties keep developing and changing. In the course of construction additional stakeholders join the project. When a project is big in scope and complex with numerous interested groups taking part in its realization, efficient and rational formulation, coordination and handling of needs becomes hardly manageable or possible at all both to an individual person and an interested group without computing technology and various methods (Bejder 1991).

From the examples presented above it is evident that *the stakeholders are characterized by numerous criteria*. Consequently, in order to establish rational stakeholders, it is necessary to evaluate the entire system of criteria characterizing the project under consideration in a detailed and adequate way.

Relying on the system of criteria characterizing the project under consideration objectively and exactly, as well as multiple criteria decision making methods, it is possible to establish rational stakeholders (contractors, procurers, etc.). The principal feature of a consideration objectively and exactly as well as multiple criteria decision making methods, it is possible to establish rational stakeholders (contractors, procurers, etc.). The principal feature of a rational stakeholder is making decisions for efficient solutions and processes. By the use of rational solutions and processes the project management optimal total efficiency is reached.

1.6. Modeling of Construction Project Management

Construction projects are getting bigger and more complex while the average productivity at the industry level is not improving enough. It is essential to look at the means available, in order to improve the efficiency and effectiveness of the construction industry. Technology fusion, which refers to a truly interdisci-

plinary approach of combining different technology areas, is a new way of sparking off the currently stagnant level of construction technologies. Kim *et al.* (2009a) presents a comprehensive technology roadmap developed under the support of Korea Ministry of Construction and Transportation (KMOCT), where the needs for innovative future construction technology are well organized through the interdisciplinary research efforts. To succeed in developing a technology fusion-based construction research plan, four major approaches are adopted: technology foresight, socio-economic prediction, market needs identification, and benchmarking of other efforts. Through these integrated processes, research and development (R&D) programs that cover the entire life cycle of construction projects are proposed. KMOCT is expected to launch 14 of the proposed programs during the next five years on a priority base, funding a total of approximately US$ 5 to 15 million for each program (Kim *et al.* 2009a, 2009b).

Bridge deck construction is performed in a cyclic manner and it involves different types of interacted resources. Said *et al.* (2009) present a case study that discusses how computer simulation is used to aid bridges' contractors in planning of bridges' decks, taking into consideration the interaction amongst involved resources. As such, total duration of deck execution and the associated total costs, including direct and indirect costs, can be estimated. El-Warrak Bridge, which is a part of the Ring Road of Cairo, Egypt, is analyzed in a step-by-step procedure to demonstrate the capability of computer simulation in modeling construction of bridges' decks using cast-in-place on false work and cantilever carriage construction methods. The presented methodology proves its practicality to contractors in estimating the time and costs of the repetitive process of bridge deck construction, considering complex interdependencies between construction resources and the uncertainties associated with construction activities.

The accurate and up to date measurement of work in progress on construction sites is vital for project management functions like schedule and cost control. Currently, it uses traditional building surveying techniques and visual inspections. The usually monthly measurements are error prone and not frequent enough for reliable and effective project controls. Zhang *et al.* (2009) explore the potential of using computer vision technology in assisting the project management task. In particular, they examine the development of an integrated building information system that aims to determine the progress of construction from digital images captured on site in order to semi-automate the work in progress measurement and calculation of interim payments as well as function as an early warning system of potential delays. The study focuses on the quantity rather than quality aspect of work and is limited to the superstructure of buildings (Zhang *et al.* 2009).

Lee and Ou-Yang (2009) introduce an automated tool named Stochastic Quality Function Deployment (SQFD) system, which measures the quality performance of a Design/Build (D/B) contractor. SQFD integrates stochastic simulation modeling and analysis techniques into traditional QFD to deal efficiently with the uncertainties in the input data, to support the quality performance measurement that is involved in multi-attribute and multi-participant decision-making, and to predict the variability in the output. D/B construction owners who are in the process of selecting a D/B firm for a project would benefit from SQFD, because the system allows an owner to expeditiously assess the quality performance of potential D/B firms in their bidding list. An example in D/B contractor evaluation is presented to illustrate the functioning of the system. The system helps to improve the D/B project bidding system (Lee and Ou-Yang 2009).

Timely effective cost management requires reliable cost estimates at every stage of project development. While underestimation of transportation costs seems to be a global trend, improving early cost prediction accuracy in estimates is difficult. Chou (2009) presents a parametric estimating technique applied to Texas highway projects using a set of project characteristics. Generalized linear models (GLM) of early quantity prediction for geometry-related work activities, namely earthwork, pavement and traffic control were developed for continuous project cost tracking. The approach of cost breakdown demonstrates the potential to separate quantity uncertainty from price uncertainty for highway construction. The benefit of this approach is to provide a platform for evolving the preliminary parametric cost estimates to a fully detailed cost management as further information becomes available as the project progresses. During project execution, managers are given opportunities to review the associated work activities and make better decisions from the developed GLM-based estimating system. Compared to typical practice of applying a gross cost per lane length during pre-project planning phase, the proposed approach with the aid of the developed expert system provides more detailed basis and efficiency for tracking the effects of changes within the project life cycle (Chou 2009).

East *et al.* (2009) describe an innovative application of discrete-event simulation to model and evaluate differences in business processes following the introduction of new information technologies. Validated models can be used by offices considering the new technology to calibrate existing work loads and then to predict the expected impact of new information technology on measurable business metrics. Following the introduction of the technology, this model may assist in the real-time verification of user paths incorporated in software support tools. This research evaluating the impact of information technology and public construction contract administration.

Cheng *et al.* (2009b) develop a construction management process reengineering performance measurement (CMPRPM) model based on an application of business process reengineering philosophy. Process operation time and customer satisfaction are used as efficiency and effectiveness evaluation indices. The CMPRPM model applies queuing theory to calculate process operation time in order to strike an optimal balance between process execution demand and manpower service capacity. In order to achieve customer satisfaction, customer demands are identified and a target attainability index is used to calculate process effectiveness. After integrating efficiency and effectiveness evaluation results, indices of process value (PV) and value improvement (VI) are proposed to allow performance prior to and after reengineering to be measured and compared. The proposed CMPRPM model addresses the performance of initial ("As-Is") and significantly reengineered ("To-Be") processes to facilitate successful BPR design. The results show that the construction industry stands to benefit significantly in terms of a successful BPR design by adopting the model proposed in this research (Cheng *et al.* 2009b).

Project teams face ever increasing pressure to deliver projects as quickly as possible. To meet these demands, contractors are faced with the need to explore various construction strategies in order to meet delivery dates, and to assure themselves as to the achievability and quality of a schedule. Various visual representations of a project's schedule and associated information combined with visual representations of the project in progress, i.e. 4D CAD, can assist with these tasks of identifying effective construction strategies for shortening project duration, assessing their workability, and judging schedule quality. Such visual representations aid communication amongst project staff and facilitate brain-storming, and, implemented well, they can provide clear, fast, and multi-dimensional feedback to the project team. In this research, we describe aspects of our work which is directed at formulating a dynamic visualization environment that links 3D CAD, a generalization of traditional CPM which embraces linear scheduling, dual product representations (scheduling and CAD system) and their mapping onto each other, and schedule and CAD graphics in a manner which facilitates the relatively rapid exploration of alternative construction method and scheduling strategies for large scale linear projects (e.g. high-rise buildings, bridges, etc.). Requirements of such an environment include quickness, treating scale, working at multiple levels of detail, dealing with design variability, and realistic representation of the work. Use is made of a realistic example to highlight aspects of our approach and identify important issues that must be addressed if a visualization environment useful for construction professionals is to be developed (Russell *et al.* 2009).

It should be noticed that the researchers from various countries engaged in the analysis of construction project management and its stages did not consider

the research object being analyzed by the author of the present investigation. The latter may be described in the following way: a construction project management life cycle as well as project, organizational and external environment having a particular impact on it making an integral whole. A complex analysis of the research object described was made with the help of complex systems theory and methods multiple criteria project analysis.

1.7. Concluding Remarks of Chapter 1

1. The construction project management life cycle and the project, organizational and external environment must be analyzed and described.
2. Application of information systems, neural networks, and expert and decision support systems, e-commerce at national, organization and project levels are very important tools.
3. Methods of multiple criteria analysis of integrated construction management and modeling of construction project management can be successfully applied.
4. It may be noticed that the researchers from various countries engaged in the analysis of construction project management and its stages did not consider the research object being analyzed by the author of the present investigation. The latter may be described as follows: a construction project management life cycle as well as project, organizational and external environment having a particular impact on it making an integral whole.
5. Analysis of global research showed that the existing models multivariant design and multi-criteria analysis of construction project management alternatives are the most appropriate for solving problem.
6. A set of criteria pertaining to the construction project management suggested by different researchers is presented.

2

Model for Integrated Project Management

2.1. Introduction to an Integrated Project Management

Project management in the construction involves coordination of many tasks and stakeholders, affected by complexity and uncertainty, which increases the need for efficient cooperation and multiple criteria decision making.

There is no single accepted or correct definition of project management and there are as many definitions of project management as there are people capable of defining it:

- Construction Management refers either to the study and practice of the managerial and technological aspects of the construction industry (including construction, construction science, construction management, and construction technology), or to a business model where one party to a construction contract serves as a construction consultant, providing both design and construction advice (Christodoulou 2009).
- Where a contractor is engaged to manage the construction of a project for an agreed fee and the trade contractors are engaged either directly by the client or an open book analysis (Ng *et al*. 2004).

- The application of modern management techniques and systems to the execution of a project from start to finish, to achieve predetermined objectives of scope, quality, time and cost, to the equal satisfaction of those involved (Kim *et al*. 2009b).
- Project management is a critical skill required for execution. It is an essential organizing and managerial discipline in getting things done. The art of managing the product and service development cycle to achieve a balance of time, cost and quality is project management (Cheng *et al*. 2004), etc.

The Construction Management Association of America (Palaneeswaran *et al.* 2006) indicates the 120 most common responsibilities of a construction manager fall into the following 7 categories: project management planning, cost management, time management, quality management, contract administration, safety management, and CM Professional Practice which includes specific activities like defining the responsibilities and management structure of the project management team, organizing and leading by implementing project controls, defining roles and responsibilities and developing communication protocols, and identifying elements of project design and construction likely to give rise to disputes and claims.

The primary challenge of project management is to achieve all of the project goals and objectives while honoring the project constraints. Typical constraints are scope, time and budget. The secondary and more ambitious challenge is to optimize the allocation and integration of inputs necessary to meet pre-defined objectives. A project is a carefully defined set of activities that use resources (money, people, materials, energy, space, provisions, communication, motivation, etc.) to achieve the project goals and objectives (Christodoulou 2009).

Useful techniques in project management include the concepts of cash flow and present worth, decision tree analysis, critical resource analysis and critical path scheduling (Enge and Huhnt 2008).

Integrated project management has various approaches and different priorities in different countries. It is not surprising that there are widely divergent views and interpretations in various countries, with marked differences between countries that have developed market economies, those with transition economies and in developing countries. Not all the countries with one of these three development levels, understand integrated project management in the same way and so have different strategies.

Successful strategies for integrated project management should be more-or-less compatible with economic, social, cultural, institutional, technological, technical, cultural, environmental and legal/regulatory situations in the country under consideration. A varied spectrum of strategies can be launched, while

keeping in mind that the mix of influencing factors and the relative emphasis is on one or other of the factors and overall will depend on local conditions.

It be noticed that the researchers from various countries engaged in the analysis of construction project management but did not consider the object of research was analyzed by the authors of the present investigation. A life cycle of a construction project management may be described as follows: the stakeholders involved in its design and realization as well as the project, organizational and external environment, having a particular impact on it and making an integral whole.

2.2. Knowledge Management Models and Theories

Construction organizations use various knowledge management strategies: experts data bases; cross construction project learning; active knowledge management (this knowledge management strategy is also referred to as the push strategy or codification approach); knowledge requests of experts (this knowledge management strategy is also referred to as the pull strategy or personalization approach); knowledge mapping; rewards (to motivate experts to share their knowledge); communities of practice; best practice transfer; competence management (continuous employee qualification improvement and assessment in organizations); expert-apprentice relationship; groupware technologies; knowledge databases and bookmarking engines; intellectual capital; knowledge brokers; social e-network; storytelling (transfer of tacit knowledge); after construction project reviews; etc. Some of these strategies (community of practice, social network, intellectual capital) are part of various knowledge management models and theories. Above models and theories, as well as their application in construction, are briefly analyzed in the following paragraphs.

Social network analysis is the mapping and measuring of links and relationships between organizations and individuals engaged in Networking or collaborative activities. It may reveal: specific expertise or influence; how people cooperate, and with whom; who is overburdened with requests for assistance; and who fails to collaborate at all. Since it provides both visual and mathematical analyses, it is a very powerful technique for evaluating mergers and acquisitions, joint ventures, and inter-company relationships (Quantum 2009). Kurul (2007) analyzed possibilities to evaluate knowledge creation capability and absorptive capacity in construction on the basis of the methodology of social network analysis. Kurul (2007), in the project funded by EPSRC (EP/C530160/1), analyzed the concepts of absorptive capacity and social capital, while analytical techniques such as social network analysis were deployed

to evaluate knowledge creation capacity of project teams in the construction industry.

Community of Practice is a community or group with a common interest. Community of Practice frequently use the internet to facilitate their activities. This facilitation may include forums, libraries, chat rooms, calendars and such as working researches, links, and a contacts directory other goodies are shared here for all to use (Wason 2009). Yu (2009) presented the development of the knowledge value-adding model (KVAM) for quantitative performance measurement of the community of practice of the knowledge management system in an A/E consulting firm. The proposed KVAM combines several existing KM theories including knowledge creation spiral, knowledge chain model, and knowledge value added theory to form a process-level model for measuring the performance of a generic community of practice. Love (2009) uses the normative literature to develop a proposal for using communities of practice in construction projects. An inter-organizational form of community of practice, known as "champions of practice," is propagated for use in the construction industry. The "champions of practice" is developed as an active know-how platform to provide advice pertaining to issues of "best practice" that have been accumulated from projects. The creation of such a form of community of practice can provide invaluable insights about best practice, which can be formalized and shared in a meaningful and reflective way.

Intellectual Capital is the same as the knowledge asset of an organization. Knowledge assets help achieve business goals. This capital is the set of intangible assets that includes the internal knowledge of employees have of information processes, external and internal experts, products, customers and competitors. Intellectual capital includes internal proprietary reports, libraries, patents, copyrights, and licenses that record the company history and help it plan for tomorrow (Stuhlman 2009). Bartholomew (2008) describes developing expertise, creativity and intellectual capital in the construction professions. He shows design practices and other construction professionals how to manage knowledge successfully. Design is a knowledge-based activity, and project managers, contractors and clients, as well as architects and engineers, have always learned from experience and shared their knowledge with immediate colleagues. Increasingly sophisticated construction technology and more demanding markets are making effective management of knowledge ever more important (Bartholomew 2008).

Information theory is based on the fact that we can represent our experience by the use of symbols like the alphabet, pictures, etc. It is concerned with the problem of how to measure changes in information or knowledge content, that is, how to compile or interpret a message (Skyttner 1998). The main

propositions of information theory are broadly applied in the development of knowledge management and intelligent systems for construction.

Real-world complex systems are almost always made up from a large number of interacting components. This leads to complex behavior that is difficult to understand, predict and manage. Researches on complex systems are often undertaken by mathematicians, statisticians, engineers, and information and computer scientists (Australian 2009). Many large construction projects are attributed to complex systems. Therefore, accumulation of experience and knowledge, as well as its multiple reuses, in such large construction projects is of particular significance.

Many knowledge management models and theories are, in one way or another, based on various philosophical theories. The Constructivism Model is not an exception. Philosophy is dealing with knowledge since ancient times. The specified problems of the traditional knowledge theory form the nucleus of classic epistemology. Epistemology is an area of philosophical study that focuses on our understanding of knowledge. Epistemology asks questions about what is true and false, and what constitutes valid "information". A key question of epistemology is whether information is absolute or relative, reflecting a tension between the "scientific method" and "social constructivism" (Trinity College 2009). Cognitivism is the one of the younger branches of epistemology – deals with consistent patters of scientific cognition. The idea of cognitivism (Macmillan English Dictionary 2009) is that learning is a conscious, rational process. People learn by making models, maps and frameworks in their mind.
In cognitivism (Trinity College 2009) knowledge is viewed as symbolic, mental constructions in the mind of individuals and as the outcome of learning. Learning is a process of recognition which occurs with associations through contiguity and repetition. Thus, learners perceive new relations among the parts of a problem, they acquire and reorganize information into understandable cognitive structures.
Cognitive science is usually defined as the interdisciplinary study of how information is represented and transformed in the mind/brain. It consists of multiple research disciplines, including psychology, artificial intelligence, philosophy, neuroscience, linguistics, anthropology, sociology, and education. It spans many levels of analysis, from low-level learning and decision mechanisms to high-level logic and planning; from neural circuitry to modular brain organization (Wikipedia 2009a).

Constructivist epistemology is an epistemological perspective in philosophy about the nature of scientific knowledge (Routledge 2000). Constructivism is a philosophical perspective derived from the work of Immanuel Kant which views reality as existing mainly in the mind, constructed or interpreted in terms of one's own perceptions. Constructivism focuses on the process of how

knowledge is built rather than on its product or object (Constructivism 2009). Constructivism is a theory of knowledge which claims that knowledge is not passively received but actively constructed by the learner, and that the function of cognition is adaptive, serving to organize experience, rather than discover reality (Glosary 2009). Constructivism is a philosophy of learning used by the leading construction organizations to master the best construction practice.

2.3. Model for an Integrated Project Management

The research's aim was to produce a Model for integrated project management by undertaking a complex analysis of project, organizational and external environment factors affecting it and to present recommendations on increasing its competitive ability. The research was performed by studying the expertise of advanced industrial economies and by adapting it to Lithuania by taking into consideration its specific history, development level, needs and traditions. A simulation was undertaken to provide insight into creating an effective environment for the Model by choosing rational project, organizational and external factors (Fig. 2.1).

The level of efficiency of the integrated project management depends on the many projects, organizational and external variable factors and all these variable factors can be optimized. The main objective of this Model is to analyze the best experiences in the field, to compare it and consequently to present particular recommendations. In this particular case, the construction management development perspectives of Lithuania were analyzed.

The word 'model' implies "a system of game rules", which the integrated project management development could use to its best advantage. The stakeholders of an integrated project management cannot correct or alter the project, organizational and external variables, but they can go into the essence of their effect and take them into consideration in their activities. Stakeholders, by knowing the environment affecting their projects, can organize their present and future activities more successfully.

The Model for an integrated project management includes the following six stages:

Stage I. Comparative description of an integrated project management:

- A system of criteria characterizing the efficiency of an integrated project management was determined by means of using relevant literature and experts methods;
- Based on a system of criteria, a description of the present state of integrated project management is given in conceptual (textual, graphical, numerical, etc.) and quantitative forms.

Stage II. Comparison and contrast of integrated project management techniques includes:

- Identifying the global development trends (general regularities) of an integrated project management;
- Identifying the integrated project management differences between countries;
- Determining pluses and minuses of these differences;
- Determining the best practice for an integrated project management for Lithuania as based on the actual conditions;
- Estimating the deviation between construction managers' knowledge of worldwide best practice and their practice-in-use.

Stage III. A multiple criteria analysis of integrated project management's components and a selection of the most efficient version of the project' management life cycle were determined at this stage. After this stage, the received compatible and rational components of an integrated project management are joined into the full integrated project management process.

Stage IV. Development of some of the general recommendations as how to improve the efficiency levels for construction managers and construction firms.

Stage V. Submission of particular recommendations for construction managers and construction firms. Each of the general recommendations proposed in the fifth stage carry several particular alternatives.

Stage VI. Performance of transformational learning and redesigning the mental and practical behavior:

- Construction managers (firms) becoming aware and conceptualize of their practice-in-use;
- Construction managers' (firms') becoming aware and conceptualize of their knowledge of worldwide best practice;
- Construction managers (firms) estimating the deviation between knowledge of worldwide best practice and their practice-in-use;
- Performance of best practice learning;
- Fulfilling of best practice actions (understanding what the recurring motives caused manager' initial behavior are; redesigning managers' core patterns of thought and behavior);
- Performance of transformational learning (acquiring new manners of technological, social, ethical, etc. behavior, get better understanding of how to interact with project, organizational and external environment) and redesigning the behavior.

In order to throw more light on the Model for integrated project management, further follow more detailed description of some the above mentioned stages of the analysis (the effect of changing the project, organizational and

external efficiency level factors on the efficiency of integrated construction management; methods of a multiple criteria analysis of integrated construction management; performance of transformational learning and redesigning the manager' mental and practical behavior).

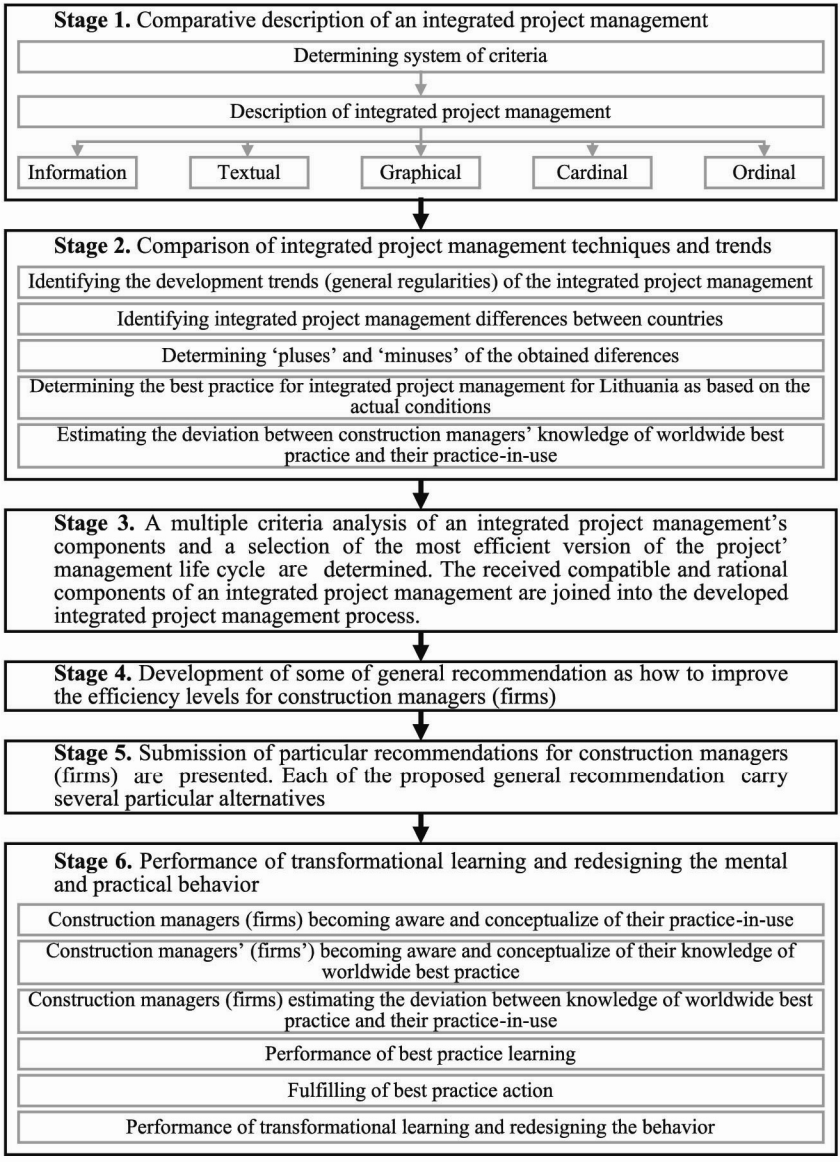

Fig. 2.1. Conceptual model for an integrated project management

2.4. The Effect of Changing the External Efficiency Level Factors on the Efficiency of Integrated Construction Management

One of the major tasks of a construction manager is to carry out its activities under the most favorable project, organizational and external environment conditions. Efforts are made to ensure that the structure, goals, output, efficiency and quality of production of the organization would be in maximum conformity with the existing environmental conditions. The pursuit of impracticable goals, for instance, trying to realize projects which surpass the organization's capabilities or the environment (economical, social, legal, political, competitive and technological conditions) is adverse, may cause undesirable consequences.

In order to assure the efficiency of a project management, it should be executed within certain bounds which are determined by project, organizational and external level factors. The highest level at which efficiency factors may be considered is the external efficiency level factors. The level of efficiency and the scope of activities of the project management depend on the different external level variable factors (see Fig. 2.2). As an example, some above mentioned external efficiency level factors further are discussed briefly.

Miller (1992) argued that international firms are exposed to five types of international risk: natural, legal, societal, political and governmental. Daniell (2000) confined such risk to four components: financial, cultural, legal and political. Similar components were reported by Hill (2002), excluding financial risk. Butler and Joaquin (1998) defined the term as the risk that a sovereign host-government will unexpectedly change the 'rules of the game' under which a business operates. Political risk, as suggested by Brink (2004) and Stosberg (2005), arises not only from governmental, but also societal, sources. Howell's (2001) referred the term political risk to the possibility that political decisions or political or societal events in a country will affect the business climate in such a way that investors will lose money or not make as much money as they expected when the investment was made.

Typically, political risk insurance, as reported by Bradford (2005), covers assets against expropriation, confiscation, contract repudiation and currency inconvertibility. Political risk, meanwhile, should encompass all political and societal events that can harm international projects, internal or external, insurable or uninsurable and favorable or unfavorable (Wilkin 2001).

Governments, according to Burmester (2000), are extremely influential actors in international business. A government has a variety of interests and may pursue a course of action that affects the business environment for good or bad. The government of a country, on the one hand, is usually keen to encourage the development and growth of commerce and industry (Al Khattab *et al.* 2007).

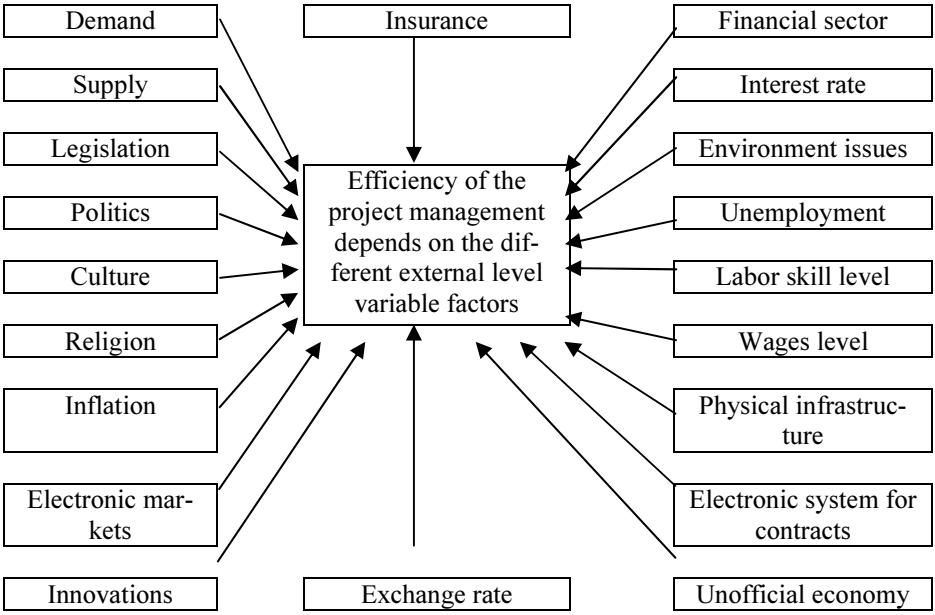

Fig. 2.2. Efficiency of the project management depends on the different external level variable factors

The government, as a result, might offer incentives to encourage new investment from abroad, for example by offering tax incentives or cash grants towards the building of factories. To the host-government, as explained by Brink (2004), international projects can represent an important source of funds, technology and expertise that could help further national priorities such as regional development, employment, import substitution and export promotion. The government of a country, on the other hand, may also intervene in the business environment for a variety of reasons. Such reasons include: protecting national industries from external competition; limiting foreign exploitation; increasing national welfare; redistributing wealth (Bartlett *et al.* 2004).

Taxation can also be used either to encourage or restrict particular industries. In the event of imposing taxation restrictions, a firm's expenditure increases and, as a consequence, its profits decrease. However, as a result of the importance of foreign investment to a country's economic growth, a government may encourage inward investment by, inter alia, offering tax incentives (Chartered Institute... 2001) rather than imposing tax restrictions. The importance of foreign investment to a country's economic growth may, therefore, explain the little attention paid to taxation restrictions by international projects, while operating internationally (Stosberg 2005).

A government may terminate contracts without compensation for existing investment for reasons related to contract performance. Since such risk can have devastating impact upon firms, the breach of contract, according to Moran (2001), is considered as an important risk of concern to international projects. In this context, firms with large fixed assets are more vulnerable to such risk and still "worry" about the terms of their operating agreements being changed (Kettis 2004).

In order to throw more light on the external efficiency level factors, further follow more detailed description of the operation and development of electronic markets as prognostic instrument for business planning and the development of an electronic system for contracts and the execution of building work in Germany.

2.5. Operation and Development of Electronic Markets as Prognostic Instrument for Business Planning

2.5.1. Introduction to Electronic Markets

Competition for private enterprises is aggravated by the worldwide increasing deregulation of the markets. Good knowledge of the markets on which the individual enterprise acts as well as the increasing understanding of the market activities are important factors of success for the management. Significant influences on the success of the enterprise can be broken down into the following segments (Lechner and Müller-Stewens 2003):

- Economy, e.g. inflation rates, interest rates, unemployment.
- Politics and law, e.g. tax law, patent law, and political stability.
- Socio-cultural influences, e.g. population development, age structure, consumer behavior.
- Technology, e.g. innovation, knowledge transfer.

The analysis and processing of information about expected future occurrences in one of the above-mentioned segments is an essential basic principle of strategic planning. Thus, for example, the determination of sales forecasts constitutes a central element within the business planning.

A precondition of successful planning is the preparation of the decision and the development of predictions for the future. A statement that is accurate as possible about the probability of future events occurring is also an essential element of the risk management. Numerous instruments were developed for the drawing up of forecasts, in which a distinction is made between quantitative and qualitative methods. While quantitative prognostic instruments establish a

connection between values forecast and the influencing factors considered for the forecast with the aid of a prognostic functions, qualitative prognostic instruments are based on estimates of future developments. They are especially suitable for developments and occurrences that are difficult to predict, e.g. for sales forecasts for new products, in the event of innovation or the evaluation of the effectiveness of new marketing measures.

2.5.2. The Delphi Method as an Established Prognostic Instrument

A lot of prognostic methods include the Delphi method. The Delphi method was originally developed at the RAND Corporation by Dalkey and Helmer 1963 to systematically solicit the view of experts in controversial sociopolitical areas of discourse. By the late 1960s, the use of Delphi was applied to technological forecasting.

Besides, the whole process of the Delphi methodology can be time consuming. These drawbacks led executives of the company to wonder whether a multi-criteria evaluation method was available to more effectively guide and supplement their existing selection process (Lai *et al.* 2002).

The Delphi method is an established prognostic instrument, a qualitative technique of repeated questioning of experts that aims, through intensive questioning, at using the knowledge of the experts for the formulation of forecasts. In this, the experts in a special area are questioned in writing and anonymously about the subject matter of the investigation in several waves of questioning.

Normally, each person questioned is initially asked to give a written forecast that is as differentiated and well-founded as possible. The results of this wave of questioning are then analyzed and passed back to the experts before the next wave, all the while observing the anonymity of the persons, stating the average values and dispersion for the review of their own position and in particular their forecast given beforehand. In the second wave they are then asked with more specific questions to review their previous forecast once again and if necessary state reasons why they have revised or kept to their first forecast in the second questioning. The process can be continued until a clear majority has formed or the experts questioned are no longer prepared to revise their forecasts.

The basic concept of the procedure is the gradual achievement of a consensus through a feedback technique that deliberately tries to avoid the pressure to conform that frequently emanates from group discussions. There are, however, legitimate doubts whether this attempt succeeds, since a fellow traveler effect through the orientation of the experts to the judgment of the group at least appears very plausible.

The Delphi method is in particular used for long-term technological forecasts. The advantage of this method is that the formation of a consensus among experts striven for is normally achieved in practice and that the results gain in quality through repeated feedback. The disadvantage is the effect of the high cost in terms of time and finance and the relatively long throughput times. Moreover, it has become evident that the forecasts by the experts tended to be too optimistic and impediments to implementation and market antagonism were underestimated.

2.5.3. The Further Development to an Electronic-Based Prognostic Instrument

The functions of markets not only include the allocation of resources, but also the gathering of information about the value of these resources. An example of information that was gained from markets and used in enterprises is share prices that furnish the enterprises with information about the value of their activities. Futures and securities options sum up the expectations of the investor regarding the occurrence of future values of securities. In most cases, forecasts of the future are also a side-effect of the market activity. On the other hand, now, however, markets have been created with the main objective to evaluate the knowledge of the market participants for the gaining of information.

In recent years electronic bourses have been the subject matter of numerous studies in the USA. In the ‘80s, an electronic market place was created at the University of Iowa, originally to provide the students with the possibility to operate trade on an Internet platform and thereby to get to know market legitimacies (Lechner and Müller-Stewens 2003). This gave rise to the idea to use electronic markets for the aggregation of information. There arose so-called prediction markets with the objective to achieve a crystallization of information through the market's own dynamism and thus be able to make predictions of the future with a higher probability that the predicted event will occur. The observation of these markets is the subject matter of various scientific investigations that provide important results for the operation in enterprises.

2.5.4. The Recipe for Success of the Electronic Markets

The system of the prediction markets uses the medium of the Internet for questioning, as the market place for the probability that events will occur. In the electronic market, one of the basic problems of qualitative procedures relates to the difficulty in selecting experts who are able to make corresponding informative statements about the future. Electronic markets are distinguished by a high number of provided and buyers as well as through the absence of hierarchies. A uniform product is traded: the bet on the occurrence of an event.

For prediction markets, the following characteristics apply:

- Simplified market access, any time, any place.
- No information asymmetry, i.e. each participant obtains the same information about the product "bet".

The marketing results are influenced by the market participants and their expectations, experience and their interpretation of the market information. They are suitable as prognostic instruments, for they have a high rate of accuracy. This is also shown by the example of I.E.M Iowa Electronic Markets. Here, above all, bets are placed about the occurrence of political events; the predictions constantly outperform the results of other election polls.

Another successful example is the Hollywood Stock Exchange. In 2002, here 45 of 50 Oscars were forecast correctly; bets were made with play money, so-called Hollywood dollars. The probability of an accurate prediction is, however, lower when using play money than in the case of real bets. Bets on sporting occurrences can also be made in the Internet, e.g. on the website trade sports.

Instead of using the advice of a selected body of experts as a source of information, as in the case of the Delphi method, information accessible to the general public is sought in the Internet. In this, an incentive to pass on information is the game and the profit hoped for. In the game, the ambition of the market participant is aroused by the best information. Market results are all the more accurate the larger the number of those participating and the number of market activities and the fewer possible occurrences that are available for selection.

Electronic markets gather information from individual participants. The knowledge available to these, emanating from various sources, is assessed at the value of the resulting market price. The more each participant invests in a betting stake, the more accurate his/her information is and the smaller his risk of loss is. In this, there are no hierarchies; everybody has just as much influence; all opinions are valid. In the scope of prediction markets, there are no speculation bubbles, as, for example, are known from the stock markets, since they are normally made subject to a time limit and geared to a certain result. By setting a fixed deadline, in the end, everybody wants to "pass the buck" and unsound overvaluations are adjusted promptly. Many years of observations by Iowa Electronic Markets have shown that above all markets that are geared to occurrences lying in the near future provide particularly effective results (web page: http://www.biz.uiowa.edu/iem/about, IEM 2009).

Prediction markets thus open new ways for market research. In contrast to established procedures, they are distinguished in that they accumulate complex market information dynamically and thus make possible very much shorter reaction times than with traditional methods.

2.5.5. The Function of the Prediction Markets

The function of the prediction markets will be explained briefly in the following section.

One possibility of the development of electronic markets is the so-called linear markets.

Bets are made on the occurrence of a future event with the possible variation v_1, v_2, v_3 … v_n, the result of which is the sum 1.

Prediction markets that were supposed to predict such occurrences would thus have chances of winning corresponding to the occurrence of the events. If, for example, percentages that candidates achieve in an election are to be determined, a market would be created, in which the market participants deal with securities with the value that corresponds to the result of the election forecast. The market price of the betting slips results in the prediction of the election outcome. Bets are made on the election result of the individual parties in %.

After the occurrence of the event, each security obtains 1$ multiplied by the share of the party that has betted in the overall result. A second kind of prediction markets is the so-called "the winner takes it all" procedure. All shares are bundled as uniform portfolios consisting of all possible variants, put into circulation at a fixed price. Transactions between the traders occur at prices that were created by the market participants. The buyers can trade at the current market price or set limits.

2.5.6. Outline Conditions for the Gain of Information by Prediction Markets

The certainty effect describes the inclination to attach a disproportionately great importance to events that are certain to occur. If two test persons for example have to decide on the election for 30$ with a 100% probability of the predicted event occurring or for 45$ with an 80% probability of the predicted event occurring, the overwhelming majority would decided on the certain alternative for 30$. In a second attempt, the probabilities were kept in the same proportion, however, divided by the factor four. The test persons could now decide on the occurrence 35$ with the probability 25% or on the occurrence 40$ with the probability 20%. Here, most test persons selected the occurrence with the highest expected value, namely the occurrence 40$. Decision-makers thus do not make their decisions according to a linear function, corresponding to the probability of an event occurring, but as a rule also decide on a certain alternative, if available, when this rationally does not represent the best alternative. The closer the probability of an event was occurring lies to 100%, the more likely the persons selecting are to decide on this occurrence.

The effect of the immediacy shows parallels to this. In this, decision-makers attach disproportionate importance to immediately occurring occurrences. Thus, they preferred for example 30$ today in comparison with 45$ in one year. If both possibilities 30$ in one year or 45$ in two years could be selected, however, the test persons selected 45$. If a decision-maker has the choice between an immediately occurring alternative or a possibility occurring only later, he/she will rather decide on the event occurring immediately, even if this alternative is purely rational for him/her and not the most favorable economically.

A further characteristic feature of human decision-making that can lead to errors in forecasts is the effect of wishful thinking, also referred to as unrealistic optimism (Weber and Chapman 2005). The studies by social scientists show that individual persons overestimate the spread of their own views in the population. For this reason, the chances of the party preferred by the selector are overestimated. This can now lead to the outcome that based on this overestimate, more shares of the preferred party are acquired than would be expected on the basis of the existing information. Furthermore, it was also established that so-called "good news", i.e. favorable information for a party, tends rather to be spread by market participants where the party preferred by him/her is concerned. Also, in electronic prediction markets arbitration effects can occur, which can falsify the result. If prediction markets are to be used as prognostic instruments, phenomena such as those represented above must be taken into consideration both during the development of the market and during the evaluation of the results.

2.5.7. Future Possible Uses of Prediction Markets

Prediction markets are distinguished above all by the following characteristic features:

- They provide a stimulus for the search for information.
- They are an incentive for the true and accurate passing on of information.
- They bring about the aggregation of various opinions and are a collecting tank for information.
- They provide predictions with a high degree of accuracy in a brief period.

For these reasons, they are suitable to provide enterprises with forecasts for occurrences that affect the future of the enterprise. By using the market information from artificial markets, risks can be better assessed and hence crises are anticipated.

For enterprises, this gives rise to the chance to gather the collective intelligence of their employees and use this as a valuable information basis for future management decisions. Especially in the service sector, the employees interact

closely with the customers and, gain essential findings about customer needs. It appears meaningful, therefore, to retrieve this experience and use it for the further development of the range of goods and services provided by the enterprise. Thus, strategic business planning could no longer be determined by the executive management focusing on the main points, but on the basis of the knowledge existing in the entire enterprise.

An electronic market has now been created with 10 possible alternatives for future sales figures for the product concerned for the month defined. In this, the sellers could in each case bet on one range; result 1 represent the sales figures from 0 to 1500, result 2 from 1501 to 1600 etc. Only the share with the range in which the sales actually achieved were in the month concerned generated a profit of 1$. The development of the prediction market thus corresponds to a "the winner takes it all" procedure as described above. Each participant obtains 20 shares of each alternative at the beginning.

The participants can then trade freely with the shares in the course of a few days. The objective was to show whether the price of the respective betting slips actually permitted a statement about future sales figures. Actually, the sales range from 1901–2000 achieved the highest price, i.e. the seller of the enterprise assumed these sales figures as the most probable. This experiment was repeated 16 times in the enterprises concerned, and the results ensuing from this were 15 times closer to the sales figures actually achieved than the predictions that were made with other prognostic instruments.

The enterprise Hewlett-Packard already uses artificial markets for sales forecasts. Employees could buy fictitious shares, depending on how they estimated the sales success. After three years, the predictions were 75% more accurate than with traditional prognostic instruments. In this, while only a smaller group of employees were addressed, however, the employees were selected from all departments of the enterprise in order to be able to tap as many different sources of information as possible. In addition, uninformed speculators were involved in order to ensure the liquidity in the market and limit illogical market behavior. In this, the market provided more accurate results than the management questioned.

Also in the case of Siemens, electronic markets are already used for predictions. In collaboration with Vienna University of Applied Science and Siemens Austria, a field test regarding the possible use of a prediction market in the project management was carried out.

A considerable challenge in project management is the controlling of set dates and deadlines and the associated costs. However, the sooner delays are established, the easier it will be to guarantee the success of the project. In the scope of software development project from the telecommunications sector with ca. 200 employees and a planned term of 6 months two prediction markets were

created. In this, the two questions put were as follows: “Is the project completed on schedule?” and “How long will a possible delay last?” It turned out that the project employees detected very early that delays would occur in the project, although the check of the official project time schedule still resulted in no deviations.

Particularly the construction industry, as a sector strongly influenced by fluctuating economic cycles, is independent of a good assessment of the future chances of the enterprise. Engineers and architects, as service providers, have the opportunity to collaborate closely with their customers. This concerns in particular the project teams, which mostly manage a building project in an interdisciplinary way jointly with the customer. For the executive management, it is now decisive for the success of the enterprise to request from their employees the information of this generated in the course regarding the requirements of their customers, any future building materials.

The electronic markets might be suitable for this. An operation in the planning office is quite conceivable, in particular as well as because in the offices of small and medium sized enterprises the work with the Intranet or with a project-specific Internet-based project room has been established. Reservations of the employees with regard to the medium of the Internet are therefore not to be feared.

2.6. The Development of an Electronic System for Contracts and the Execution of Construction Work in Germany

2.6.1. Introduction to Electronic System for Contracts

The basic idea of the European Union is that by forming a common market and an economic and currency union in the long-term a unified Europe may also be achieved. For the promotion of the European internal market, the following essential basic principles apply: free trade of goods and services, prohibition of discrimination on grounds of nationality, restriction of the right of establishment, prohibition of the grant of unauthorized subsidies as well as uniform trade practice rules. To help get the idea of the European Community accepted also by the contracting authorities the European Union has regulated by coordination directives on what criteria public contracts may be awarded.

Under the term electronic government, government departments are using electronic media to an ever greater extent, both at the interface to citizens and enterprises, as well as internally. A precise estimation of the potential benefits of the use of new technologies is, however, very difficult to carry out. It may be

assumed, however, that in the course of the realization of comprehensive e-Government, considerable importance is attached to the organization of the workflow management (Scheer *et al.* 2003). The experience in e-business has already shown that the implementation of sophisticated technology-based solutions is no guarantee of business success. For the benefit of citizens and the economy, reliable and integrated services must be provided. The government department at the same time is given the chance to develop into a service provider which with the help of lean processes acts flexibly and economically to the satisfaction of its customers (Timmers 2003).

Deutschland Online is the joint E-Government strategy of the Federal and Laender governments and local authorities. Federal Chancellor Gerhard Schroder and the heads of the government of the Laender decided during their conference on 26 June, 2003 on a joint strategy for integrated e-Government Deutschland Online in order to create a cohesive e-Government landscape in Germany. On the basis of this strategy the heads of government agreed on 18 December, 2003 on 20 joint projects with which administrative services will in future be rendered via the internet. According to the basic principle "some for all", the Federal and some Laender governments or local authorities are proceeding with model solutions. The other partners are meant to profit from this, through coordinated procedures, but without central bureaucracy, by being able to use the solutions worked out for themselves. An essential element here is the optimization of public procurement. Thus, according to the Federal Minister of the Interior Otto Schily, all federal authorities should convert their procurement to electronic system for the award of public projects procedures up to the end of 2005.

With the strategic project e-system for the award of public contracts the Federal Government is pursuing the aim of handling public procurement entirely over the internet. With the e-system for the award of public contracts, due to the market transparency, completely new possibilities to obtain public contracts now exist. The project thus satisfies the requirements of the EC Treaty as well as the above-mentioned basic principles for the promotion of the European internal market.

The contract volume of the Federal and Laender governments and local authorities is considerable: in the year 2002, this amounted to 260bn. Euros, i.e. 25% of government spending and 13% of the gross domestic product (Brown *et al.* 2007). A significant role here is played by contracts for the execution of building work.

2.6.2. Electronic Contracts for the Execution of Construction Work

The traditional invitation to tender and award of contracts for the execution of construction work today is characterized by numerous media disruptions from research to digital form and vice versa. The aim of the electronic solutions is to simplify and curtail the process flows in the award procedure.

Legal and Technical Standards

The Unfair Trade Practices Act [Gesetz gegen Wettbewerbsbeschränkungen (GWB)] provides that contracting authorities, when awarding a contract in accordance with the terms of the Public Procurement Regulations [Vergabeverordnung (VgV)], must apply the provisions of the contracting regulations. These provisions must be applied if a contract for building work, deliveries or services is awarded by one of the contracting authorities stated in section 98 and a certain threshold value is reached or exceeded.

The object of the building contracts is the execution and accordingly planning of building projects as well as the execution of building work. Supply contracts are contracts for the procurement of goods that in particular relate to purchase or hire-purchase, leasing, rent or lease with or without a purchase option. Contracts for carrying out services are contracts that relate to services and are neither building work nor delivery services. The following contracting regulations apply, for the award of the diverse contracting parties:

- The Regulations for Contracts and the Execution of Construction Work Vergabe- und Vertragsordnung fur Bauleistungen (VOB)], Part A, for the award of building contracts.
- The Regulations on Tender Procedures for Supplies and Services [Vergabe- und Vertragsordnung fur Leistungen (VOL)], Part A, for supply contracts.
- The Professional Services Contracting Regulations [Vergabe- und Vertragsordnung fur freiberufliche Leistungen (VOF)], for service providers that cannot be described unequivocally and exhaustively in advance.

With the Digital Signatures Act (Signaturgesetz) and the amendment of the VOB in June 2000, the legal foundations for the digital award were laid. Through the new Regulation on Provisions for the Award of Public Contracts [Vergabeverordung (VgV)] that came into force on 1 February, 2001 a legal framework was created.

Paragraph 15 VgV stipulates that insofar as the individual contracting regulations contain no provisions regarding the submitting of tenders electronically, in the case of public invitations to tender, contract awarding authorities may permit the submitting of tenders in forms other than the research form. An

essential precondition for the validity of the procedure is that the confidentiality of the tenders is guaranteed. For this, digital tenders must be encrypted within the meaning of the Digital Signatures Act. The encryption must be maintained until the end of the deadline for submitting tenders. This legal regulation is based on the implementation of the corresponding EC Directives. It obliges the Member States to implement the electronic system for the award of public projects into national law. In Germany, this occurred through section 15 VgV and section 21 no. 1(1) VOB/A.

In the event of an electronic system for the award of public projects, it must be guaranteed that each tender can be clearly identified and its tender is kept in safe custody unchanged and unopened until the deadline for submitting tenders.

The decisive factor here is the Digital Signatures Act (SigG), which entered into force on 16 May, 2001. Under section 2 SigG, electronic signatures is "…data in electronic form, which is enclosed with other electronic data or logically linked with it, so that it serves the purpose of authenticating this". Making legally binding declarations is possible with the advanced electronic signature. These are based on a qualified electronic certificate. Such a certificate is provided by a registered or voluntarily accredited provider of certification services and is created utilizing a secure signature creation unit. It includes a personal chip card as well as a card-reading device and the corresponding certified software for each person signing.

The digital signature is realized technically by applying the public key concept (Brown *et al.* 2007). The two keys, one open, available to everyone (public key) and the other private (private key) are used. One of these also refers an asymmetric procedure type of encryption.

The principle of asymmetric encryption consists in data made illegible with the help of a public key only being made legible again with the corresponding key. The so-called providers of certification services are responsible for the authentication and the integrity of the keys. They check the identity of the participants, create the public and private key, certify these and keep a list of all participants. The private key is saved on a chip card with a PIN number and the public key in a directory available to everybody in the internet. Thus, the public key is accessible without any problems and signatures can be checked for authenticity.

If the person signing wishes, in addition, a time stamp may be created by the provider of certification services. This has the advantage that it can be reconstructed subsequently when exactly a document was signed. Just as simple as the creation of the digital signature is also the check by the recipient. The signature software also required by the recipient downloads the public key

from the public directory in the internet. The legal and technical framework for the award by digital means is thus provided.

Current Practice in the Award Process

Independently of the project circumstances, current practice in the award process takes the following form. In large-scale projects, the project planning is frequently not only carried out by one planner, but broken down into planning and invitation to tenderer. In this case, the planning must be handed over to the planner putting out to tenderer. The project planner draws up the plans by means of CAD, lets them be plotted out and sends them by messenger or a similar service to the planner putting out to tenderer. Plans are also sent via e-mail or on data carrier. If the list of services is compiled, it must be sent for reading to all project coordinators. After a correction following this, the list of services, including all required plans, is finally forwarded to the tenderers.

They now draw up their tenderer for the project phase that is being put to tenderer, in most cases per EDP. At the same time, however, this means that the data printed out on research beforehand must be reintegrated into the corresponding software.

Once the tenderer has calculated its tender, it prints this out again and returns it with a legally valid signature to the authority awarding the contract. The tenders are kept there closed and in safe custody up to the opening date. Only tenders submitted in good time prior to the deadline for the submission of tenderers are admitted. During the opening, a first, unevaluated result is read out; subsequently, all tenders must be checked as regards their contents and calculations; from this, a final price comparison list is drawn up. This makes a high expenditure in manpower necessary. The tenderers are mostly also supplied with a version of the list of services on floppy disk, including the necessary software in order to be able to open this. They are, however, not forced to submit a quote regarding their prices again on floppy disk in addition to the signed research form. In larger companies, while the return of the filled-in tenderer's floppy disk is in the meantime the norm, many smaller enterprises still balk at it. A list of services has thus changed its medium from research to file and vice versa several times up to the time of the award. Associated with this is increased expenditure of time and personnel for the activities of copying onto research, forwarding and sending by post.

The Principle of the Electronic System for the Award of Public Projects

The digital award pursues the objective to simplify the award process, thus making it more efficient. If the list of services, as previously, is compiled with AVA software suitable for this, the supporting documents are no longer printed

out and copied after completion, but transferred to the internet platform. The tenderers with access authorization have access to it and can retrieve the entire award documents digitally and upload the lists of services onto the platform again after compiling the tender.

The media disruptions of the traditional procedure are thus completely eliminated. The standardized file format of the lists of services is the GAEB format. GAEB is the abbreviation for the joint committee for electronics in building industry (Gemeinsamer Ausschuss Electronik im Bauwesen). Via the GAEB interface, as provided by the regulations of 1990 (GAEB 90) and GAEB Da of 2000, the contents of a list of services as well as the corresponding key of the standard construction services manual can be exchanged.

The procedure described above is comparable for most public awards. In the digital award processes it is now a matter of illustrating all steps technically, so that a handling free of media disruptions by the contracting authority as well as the tenderers becomes possible. How the requirements for the processes under procurement law are implemented technically will be explained in greater detail by the example. Presenting the following three projects: the e-Award Project of the Federal Government, the Electronic System for the Award of Public Contracts of the German Federal State of Bavaria and the Electronic System for the Award of Public Contracts of the City of Berlin.

2.6.3. Projects for the Implementation of the Electronic System for Contracts and the Execution of Construction Work in Germany

2.6.3.1. The E-System for the Award of Public Contracts Project of the Federal Government

In 1998, the federal government started the e-system for the award of public contracts project. At the beginning of March 2003, the Federal Office of Construction and Regional Planning cleared the first public invitation to tender in the public-sector building industry – the construction of a low-voltage current net-work for a Bonn office building via the award platform of the federal government. With the goal to be able to carry out public contracts more quickly while avoiding the traditional administrative costs for the research award, the federal government initiated the pilot project “Electronic award of federal government contracts”, in which the first building contracts have now also been awarded. Thus, a platform was created, with which the electronic system for the award of public projects of contracts of a very wide range of different services is to be handled by the federal government department in the future. The goal is the development and proving of the electronic system for the award of public projects in the internet.

When designing the e-system for the award of public contracts, three principles stood in the foreground:

- The creation of extensive legal conformity;
- Guarantee of a sufficiently secure infrastructure;
- Guarantee of the sustainability of the system.

The rules stipulated in the guidelines for the award for the various areas (VOL/VOF and VOB) and the various award types (from open procedure to a single tender action) must be reflected in the hardware and software. A direct consideration of current court rulings regarding awards was a further requirement with regard to the technical system.

Procedure and Project Coordinators

The e-system for the award of public contracts project was lead-managed by the Federal Ministry of the Economy and Work in the development and pilot phase and developed in close consultation with the Federal Ministry of the Interior and the Federal Ministry for Transport, Construction and Housing. In this, in two federal authorities is the Procurement Office of the Federal Ministry of the Interior and the Federal Office of Construction and Regional Planning (BBR) is the foundations were laid for putting the electronic system for the award of public projects to the test in a pilot study. Both of these offices were selected in order to be able to test the electronic procurement for the various award areas: The VOL, the VOF and the VOB. Accompanying scientific research analyzed and bundled the various experiences during the pilot phase, guaranteed the transferability of the results and administered their circulation. A series of federal government departments, research institutes and enterprises are working on the e-system for the award of public contracts project. Besides the federal government offices, CSC Ploentzke AG, the Fraunhofer-Institut fur Arbeitswirtschaft and Organisation (IAO) and Wegweiser GmbH in Berlin were also active. CSC Ploentzke AG, as the subsidiary of a worldwide active IT consultancy and service company, has realized a solution for the electronic illustration of the public award process in conformity with procurement law. The key elements of the solution are a highly confidential and highly available communication platform with the possibility to exchange documents as well as the use of the qualified electronic signature and the legally compliant implementation of the procedure. Fraunhofer Institut and Wegweiser GmbH Berlin cooperated in the accompanying research and the communication of the project results to the general public.

In the e-system for the award of public contracts project the following process steps were implemented technically (Böck and Kiermeier 2003):

1. Official announcement besides the well-established publication possibilities: official announcements are additionally published on the website.

2. Search for invitations to tender enterprises search electronically for public invitations to tender. In this, the electronic search function of this system is available to them free of charge. By using specifically programmed agents this search can be automated.
3. Requirement of tendering documents enterprises may be registered online and after a successful application for registration request the tendering documents via the internet. The identification and authentication of the enterprise takes place via the electronic signature; a check of the suitability takes place during the first registration.
4. Application for participation an application for participation is filed by analogy to the requirement of the tendering documents as well as the subsequent submission of a tender electronically.
5. Making available tendering documents must be downloaded via the internet, after the enterprise has been authenticated with the help of the electronic sig-nature. The tendering documents sent by the procurement office must be furnished with the electronic signature of the competent clerk in the public authority.
6. Compiling the tender and forwarding the tendering form is available in electronic form as a pdf-document. With the help of Adobe Approval the tenderers can fill in, save and sign the tendering form. The tendering form and any additional documents such as for example auxiliary tenders are forwarded electronically. Through a qualified electronic signature the tender becomes legally valid.
7. Submission and handling of the tender, the electronic handling of the tender provides an additional degree of process safety. The e-system for the award of public contracts project approves tenders only on the appointed date; until then, the tenders remain encrypted. The editorial principle according to which texts are proofread by a “second set of eyes” is satisfied by two employees of the authority awarding the contract being authenticated at the computer for the tenders by means of their signature card in order to then open the tenders. The list of tenderers and price comparison list are drawn up automatically and can be supplemented by tenders received conventionally.
8. The acceptance of the tender and notification to the tenderer the e-system for the award of public contracts project notifies the result of the invitation to tenders electronically to the participants. The decision is given its legal validity by the electronic signature. An electronic time stamp serves to control set dates and deadlines.

Technical Implementation

The most important part of the e-system for the award of public contracts project is constituted by the e-system for the award of public contracts platform. Through this, authorities awarding contracts and parties tendering communicate with one another. The main elements of the platform are formed by a webserver for the presentation of web contents as well as an application server in which processes and processing logic are saved. The webserver receives the inquiries of the users and passes these on to the application server. The application server processes the inquiries and returns the answers to the webservers, which then pass these on again to the users. The system works browser-supported, in which Internet Explorer or Netscape Navigator may be used. For the platform, a safe transfer to the internet is created with the help of firewalls.

The communication of sensitive applications with the web server flows through the transfer protocol https, Hypertext Transfer Protocol Secure, which guarantees a high degree of transfer safety. On the part of the tenderers, the application program ANA is made available as a tendering assistant for the document exchange; on the part of the authorities awarding a contract, the online procurement assistant, OBA, and the opening assistant for tenders, ÓFA are also made available. For these applications, the secure socket layer, SSL, protocol is used, which allows a safe exchange of confidential information in the internet. SSL enables the authentication of the communication partners by using asymmetrical encryption procedures and certificates and thus makes possible the confidential data transfer.

In the e-system for the award of public contracts procedure the public key infrastructure is used. In this, for a particular award procedure, closed user groups are formed. In principle, the participants identify themselves both to the e-system for the award of public contracts platform as well as in the context of a specific award procedure via its encryption certificate and the corresponding pair of keys.

Project Experience to Date

On 4 March, 2003, in the portfolio of the Federal Ministry for Transport, Construction and Housing the starting signal was given for a first complete award of contracts and the execution of building work. The Federal Office of Construction and Regional Planning released the first invitation to tender in the public-sector building industry is the construction of a low-current network for a Bonn office building via the award platform of the federal government.

With the e-system for the award of public contracts project, for the first time a public invitation to tender was handled completely electronically in a federal government department. The electronic procedure in practice has dem-

onstrated that all process steps can be illustrated and handled continuously with legal certainty. The project experience has shown that the e-system for the award of public contracts could be accessed at any time without difficulties and its availability in the operation was stable. To date, however, acceptance by the tenderers has been marginal. One of the reasons for the relatively small participation by the participants in the electronic procedure lies in the consistent use of the qualified electronic signature. In this, a less significant role has been played by the costs for the signature and the reading devices than by complications during the procurement of the signature cards. First of all, such cards could only be sourced through the party tendering Telekom. In the meantime, however, there are various other parties tendering, such as DATEV and the savings-banks so that here the service has improved. Even if further hurdles have to be removed, on the part of the enterprises great interest in participation exists.

2.6.3.2. E-System Projects for the Award of Public Contracts on the Part of the Leander, the Example of Bavaria

The Bavarian Public Authority for Building Construction works on approximately 20,000 lists of services annually in collaboration with the invitation to tender and award of building projects of the Free State of Bavaria. These are often several hundred pages thick. With the now current project “digital award” the highest building authority is now promoting innovative applications and technologies with the objective to create benefit for the potential public-sector customers and private parties tendering through a digital procedure in conformity with VOB.

Procedure and Project Contributor

A competition was initiated in order to use the innovative force of the market. In a closed procedure run in accordance with the Regulations on Tender Procedures for Supplies and Services (VOL) approximately 30 companies applied; eight applicants fulfilled the preconditions for a participation in the procedure.

The decision was made for T-Systems with the subcontractor Ventasoft. The task was on the one hand to illustrate technically the process described already under Point 2.2, and on the other hand to make available and operate a highly secure platform. T-Systems operate the integrated solution for the digital award system and provide the software solution in the computer centre. The computer centre is protected by extensive safety measures. Besides separate safety standards, a two-stage firewall concept, special data backup, monitoring and the digital signature ensure the safe operation. Ventasoft GmbH introduces the software “AVA-Online”, trains the users and provides support.

Technical Implementation

For the initial supply with a signature card and reading devices for the use of qualified digital signature, T-Systems provide corresponding product bundles. After the procurement and installation of a reading device with a signature card, the tenderer can register once only on the award platform of the Bavarian Higher Building Authority, "www.vergabe.bayern.de". During registration, the sectors or rather the project stages worked on by the company are inquired about. This makes it easier for the contract placing authority to carry out a targeted search for specialist companies in the event of restricted invitations to tenderer. During the registration, the conditions of use must be accepted. The company may immediately download the tendering tool AVA Sign, a handbook and the brief guide free of charge. For the registration and the one-off set-up on the platform, the company incurs costs in the amount of 25 Euros.

The software used illustrates the process steps from the drawing up of a text for publication to the publication online, the application by the companies, the making available of all award documents and finally the official announcement of the result of the submission. The software solution used in Bavaria has been certified in accordance with the Digital Signatures Act and confirmed by the regulatory authority for telecommunication and post. This guarantees the authorities awarding contracts and tenderers a high quality and legal certainty in the entire award process.

The tenderers can fill in the list of services and the forms in a user-friendly way with the tendering program AVA Sign. The Companies with calculation software can export the list of services from AVA Sign via the GAEB-interfaces and import the tender data via the GAEB file DA84 again into AVA Sign and check for completeness. The tendering program contains a plausibility and completeness check. In the case of an incomplete entry, warning notices appear. For the tenderers, the processing costs are thus reduced as well as the probability of procedures being excluded due to formal errors. The tender is provided with a qualified electronic signature and submitted in encryption via the award platform. The tenders then lie encrypted in a high security centre of Deutsche Telekom AG and can only be opened during the submission in accordance with the editorial principle according to which texts are proofread by a "second set of eyes". Prior to the opening date, the tenderer may withdraw its tender at any time. During the submission of tenderers, it receives a legally binding receipt with a time stamp.

Project Experience and Further Procedures

In future, construction companies will download the award documents digitally via the internet onto their computers in the workplace and edit the lists of services with their calculation programs. Small and mid-sized companies can also

do this without a calculation program and nonetheless use the advantages of the new procedure without restriction, since a simple calculation program is contained in the tendering tool. The federal Land invests around 650,000€ in the making available and maintenance of the software, the introduction of the system as well as the initial 2-year operation in the computer centre. For enterprises interested, there are information events and training courses Bavaria-wide. Bavaria started the project on 1 September 2003 in three pilot building authorities. At other government agencies the technical possibilities are being created at present, and above all the employees are being trained correspondingly. In an e-Government agreement a top to bottom implementation of the system was decided on jointly with the local authorities. At a congress taking place in Berlin "Online award of public construction contracts", the construction director Herbert Schiefil of the Highest Building Authority in the Bavarian State Ministry of the Interior reported on his experience regarding the introduction and application of the online system for the award of public contracts in Bavaria. Thus, accordingly, from September 2003 to February 2004, around 450 construction measures were put out to tender, of which up to this time 200 were online award procedures, with a participation of approximately 50% of online applicants.

Mr Schiefil also reported that the handling of the forms should be improved still further and thus an added value in the building authorities could be created through the tools used. Accordingly, what was important was also an own DSL access for the tender opening session so that the opening date could proceed punctually and quickly.

The experience to date with internet technologies has shown that a new technology is not automatically used on a broad basis as soon as this technology is technically possible. Necessary for the implementation of the electronic system for the award of public projects is therefore that it is easy to recognize benefits of use for parties tendering and authorities inviting to tender.

Preconditions for the Acceptance by the Parties Involved

The National Federation of the German Building Trade was involved in an advisory capacity in the development of the online award system of the Highest Building Authority in Bavaria. In collaboration with representatives of the building trade and employees of the building authorities concerned, the following minimum requirements were listed:

- High degree of safety through certified signature components;
- High availability;
- Conformity with the award work-flows;
- Simple, self-explanatory use;
- Cost savings potential.

A significant role in the success of the introduction of the electronic system for the award of public projects is the necessary safety of the procedure. The requirements as to the qualified, electronic signature under the Digital Signatures Act must be complied with. For this, a safe signature creation unit, a chip card with a pair of keys as provided in section 17 of the Digital Signatures Act and section 15 of the Digital Signatures Ordinance is necessary. The creation of the signature is thus legally regulated, not however the encryption itself. For this reason, the Land Bavaria has had the e-award solution confirmed not only in accordance with the manufacturer's declaration, but also through an unambiguous certification in accordance with the Digital Signatures Act and the Digital Signatures Ordinance. Also, the signature software for the award platform of the federal government is in conformity with the law through a corresponding manufacturer's declaration in accordance with the Digital Signatures Act. The safe custody of the tenders on the platform is advantageous in comparison to the traditional system. Through the digital time stamp, it is possible to comprehend through whom and at what time the tender was submitted. Thus, from a legal perspective, nothing further stands in the way of its use.

A high availability must be guaranteed by a corresponding redundancy of the system. If this is the case, an additional benefit for all parties involved is created by the e-system for the award of public contracts project, since the flexibility of the work increases. The employees drawing up the invitation to tender can access the platform at allocated workplaces independently of time and place; the collaboration is thus simplified and accelerated. The parties tendering can submit or withdraw their tenders up to the submission date, and are thus likewise more flexible in terms of time. Submitting tenders within the time specified is thus clearly simplified. While in the traditional way several days had to be planned for the packaging and dispatching of the supporting documents, these process steps cease to exist completely here.

The examples presented demonstrate how the award work-flow was illustrated technically in the projects. Various tools were developed to facilitate the work; e.g. the simple editing and the compilation of necessary forms for the award documents with the authority inviting tenders, or the automatic check for completeness and plausibility of the tender with the tenderer.

Also the criterion of the simple and self-explanatory handling is fulfilled by both platforms used at the present time. In addition, however, it is absolutely necessary to bring the technology underlying this closer to all parties involved in order to make the necessary changes more comprehensible for the persons working with it. In the above-mentioned projects, in addition information events, specially prepared material and hot line support services are made available.

In the enterprises, only minimal costs are incurred for the use of the digital signature; these are composed of the procurement of the signature card and the reading device as well as the costs for the use of the internet. In return, however, the costs for the post and the supporting documents, for which previously a fee was charged, no longer apply, while the download of the award documents is free of charge. The costs for the training of employees is likewise expected to be minimal, since the systems used are largely self-explanatory and user-friendly. On the part of the parties tendering, funds in a high amount have already been made available for the development of the systems. In addition, the expenditure for the making available and operation of the platform, internal training courses and their further development and accordingly integration of the software also fall away. Against this, there are savings potentials through the improved technical support of the process steps and through reduced personnel costs. In small and mid-sized enterprises, on a broad basis the potential for the implementation of the electronic system exists for the award of public projects and this could contribute to triggering an increase in productivity (Brown *et al.* 2007).

Unresolved Questions

From the experience of the described pilot projects, new problems have emerged. What system and what invitation to tender platform will prevail? What technical standards will be established? Various systems are already being used. Further private parties tendering are contacting the local authorities. The tendering enterprises are now confronted with a number of diverse invitations to tender platforms in the internet. A search for invitations to tender is still intricate for them at the moment, since diverse platforms have to be retrieved, and in each case a new application and accordingly registration becomes necessary.

While the operation of the platforms is largely self-explanatory, it is however varied and the technical requirements are also different. The introduction of the new workflows changes the workflow management above all on the part of the public sector; potential savings resulting from this may cost jobs (Schultzki-Haddouti 2004).

A further problem results from the handling of the certificates for the digital signature and their validity. The period of validity of a qualified certificate is according to section 14 of the Digital Signatures Ordinance restricted to 5 years, i.e. afterwards no signature can be affixed with this certificate any more; the validity is, however, in the case of accredited tenderers, verifiable for at least 30 years. Even if a provider of certification services has discontinued its business operation, through the role of the regulatory authority as a so-called Root CA by virtue of law, the permanent verifiability of the signatures is guar-

anteed. The certificates can be verified via the internet at the respective trust centre. Since, however, signature cards have to be sourced from several parties tendering, various databases must also be checked regarding the validity of the signature.

The goal of the e-system for the award of public contracts projects is the implementation of the award processes digitally. First of all, however, tenders must also be admitted in research form. Cost savings on the part of the public sector can only be realized if the majority of tenderers actually participate in the digital procedure. A proportion of 50% of digital tendering in the Bavarian project shows that in the enterprises there is widespread willingness to make change.

2.7. The Effect of Changing the Project and Organizational Efficiency. Level Factors on the Efficiency of Integrated Construction Management

The second level factors may be considered as the project and organizational level and these depend upon those at the external level. In order to efficiently implement project management, it is necessary to investigate as many of the possible alternative solutions for each variable and to select the most rational one. The selected variables are then combined into one efficient integrated project management life cycle. Hence, the efficiency of a project management will depend to a very great extent not only on the selected variables, but also on project, organizational and external factors affecting them.

The level of efficiency and the scope of activities of the integrated project management depend on the following groups of project and organizational variable factors:

- Strategy/portfolio management;
- Operations research (decision sciences);
- Organizational behavior (human resources management);
- Information technology (information systems);
- Technology applications (innovation);
- Performance management (earned value management);
- Engineering and construction;
- Quality management;
- Motivation;
- Risk management.

Project and organizational environment have a direct impact on integrated project management opportunities. This may facilitate integrated project man-

agement or, on the contrary, may create constraints. Until recently, researchers were unable to reach a unanimous conclusion as to the structure of factors of project and organizational environment and therefore several variations can be found in articles and books on this subject.

The problems related to the management of projects and project success is addressed in many studies. Sambasivan present several causes for losses in construction project management, such as a contractor's faulty planning, inadequate contractor experience, problems with subcontractors, shortage of material, non-availability of and failures in equipment, lack of communication between parties and mistakes during the construction stage (Sambasivan and Wen-Soon 2006).

Some considerations on construction project management at the construction site need to be emphasized such as a high degree of current uncertainty about the construction process, the predominance of excessively informal decision aid coming from the project manager and the exaggerated over-emphasis given by project managers to controlling time and costs. According to Cooke-Davies there have been several past studies on the success of projects and which factors lead to project success (Cooke-Davies 2002). Despite this, a project may still under-perform and an understanding of project success factors alone is not sufficient for the success of a project (Pheng and Chuan 2006).

The role of the project manager and his/her leadership style has been addressed as important aspects for the success of a project (Pheng and Chuan. 2006) although most of the literature ignores this (Turner and Muller 2005). Greek and Pullin (1999) also assert that many construction project management teams do not focus on those critical issues of projects. Project management, according to these authors, is an activity characterized by failure and these failures happen for two basic reasons: technical uncertainty and misjudgment of a project's urgency.

Baker *et al.* (1983) defined project success as follows: "If the project meets the technical performance specifications and/or mission to be performed and if there is a high level of satisfaction concerning the project outcome among: key people in the parent organization, key people in the client organization, key people in the project team and key users or clientele of the project effort, the project is considered an overall success" (Baker *et al.* 1983).

Freeman and Beale (1992) concluded that success means different things to each individual. An architect may consider success in terms of aesthetic appearance, an engineer in terms of technical competence, an accountant in terms of dollars spent under budget, a human resource manager in terms of employee satisfaction, etc.

Sayles and Chandler (1971) listed five critical success factors for a project. These are project manager's competence, scheduling of activities, control sys-

tems and responsibilities, monitoring of project and continual involvement in the project. Martin (1976) identified eight success factors in a project. These are defined goals, organizational philosophy, management support, proper delegation of duties, selection of team, proper allocation of resources, information mechanism and planning reviews. Morris and Hough (1987) found nine success factors of a project. These are clear project objectives, technical uncertainty innovation, politics, community involvement, schedule duration urgency, finance, legal agreement, contracting and solving of problems.

According to Liu and Walker (1998), project success is a concept which can mean so much to so many different people because of varying perceptions, and leads to disagreements as to whether a project is successful or not. Avots (1972) identified reasons for project failure and concluded that the wrong choice of project managers, unplanned project termination and unsupportive top management were the main reasons for the failure of a project. Hayfield (1979) established three sets of factors that determine the successful outcome of a project. According to Hayfield (1979), these are project, organizational and external factors. The external factors include realistic and thorough definition of the project, efficient manner of project execution, comprehension of project "environment" and selection of organizations for realizing the project. On the other hand, the project and organizational factors include formulation of sound project policies, clear and simple project organization, selection of key personnel, efficient and dynamic management controls and reliable management information systems.

Might and Fischer (1985) investigated structural factors assumed to affect project success. These factors include the organizational structure, the level of authority delegated to the project manager and the size of the project. They found a weak relationship between organizational structure and project success and no relationship between project size and success. Delegation of authority was found to be positively related to all internal measures of success.

Pinto and Slevin (1988) reported that critical success of a project depends on ten factors. These are project mission, top management support, project schedules, client consultation, personnel recruitment, technical tasks, client acceptance, monitoring and feedback, communication and trouble-shooting. Anton (1988) listed six factors to enhance project success. These factors are planning effort in design and construction, project manager goal commitment, project team motivation, project manager technical capabilities, scope and work definition and control system.

Belassi and Tukel (1996) categorized success factors into four main groups. These are factors relating to the project managers, the project, the organization and external environment.

A construction project is characterized by a high number of project participants and a multitude of contract relations. The Principal Agent Theory deals with the design of contracts, especially with respect to asymmetric information. Asymmetric distribution of information in co-operations can have effects before as well as after closing a contract. In construction project management therefore attention has to be paid to where information imbalances occur. Several methods are known with which one can cope with the resulting problems but which in turn cause costs (Schieg 2008, 2009).

Typically, the construction industry includes four parties: an owner, a designer (architect or engineer), the builder (usually called the general contractor), and the government (local laws and regulations). Traditionally, there are two contracts between these parties as they work together to plan, design, and construct the project. The first contract is the owner-designer contract, which involves planning, design, and construction administration. The second contract is the owner-contractor contract, which involves construction. An indirect, third-party relationship exists between the designer and the contractor due to these two contracts (Diederichs 2001).

An alternate contract or business model replaces the two traditional contracts with three contracts: owner-designer, owner-construction manager, and owner-builder. The construction management company becomes an additional party engaged in the project to act as an advisor to the owner, to which they are contractually tied. The construction manager's role is to provide construction advice to the designer, on the owner's behalf, design advice to the constructor, again on the owner's behalf, and other advice as necessary (Diederichs 2001).

Strategic planning is crucial for the survival of a company, wide-ranging decisions about future action must be taken. The information basis for such decisions is often gained from forecasts about the future with more or less accurate probability of the assumed event occurring. Electronic markets have been the subject matter of numerous investigations in recent years and if organized correctly show a high degree of accuracy in forecasting future events relevant to the business of a company. In major enterprises prediction markets have already been used successfully as a new kind of prognostic instrument. It is also suitable, however, for small and medium-sized enterprises for the gathering and assessment of the information available to the employees. When developing prognostic markets it is necessary to take into consideration psychological factors, which could favor incorrect results (Schieg 2005).

In order to throw more light on the project and organizational efficiency level factors, further follow more detailed description of the post-mortem analysis on the analysis and evaluation of risks in construction project management and risk management in construction project management.

2.8. Post-Mortem Analysis on the Analysis and Evaluation of Risks in Construction Project Management

2.8.1. Introduction to Risk and Post-Mortem Analysis

Risk management has grown in significance in the companies of the construction industry. Intense competition compels them to deal intensively with the analysis of opportunities and risks. The analysis of errors in repetitive processes plays an essential role in the evaluation of risks. Methods such as the post-mortem analysis are used in production as a standard for the further development and optimization of operations and, for this reason, for the reduction of risks.

It is fundamentally more difficult to learn from projects since every project is unique in itself. The analysis of processes, the assessment of projects, the discovery of the need for improvement and the implementation of complex alterations of the process are the core tasks of company management.

One tool for this is the post-mortem analysis. It is used today especially in IT projects; the terms “project retrospective” and “project review” are also found in the literature for this.

The post-mortem analysis is a tool for company knowledge management. In every project, the team members gain new knowledge and experiences that support future projects and broaden the knowledge of the individual employee. This knowledge must be incorporated in the risk management process. It is, e.g., integrated into check lists for the identification of project risks. Risk evaluation is simplified and made more accurate by the compilation of results from preliminary projects. Typical answers emerge from the following questions: What problems have arisen? How did problems come about? What reactions do these lead to? What costs have emerged? What risks remain? Before findings from a project can be used for new projects, ways must be found to bring them together and to consolidate the information. For example, project information packets can be tied together, which can be held in databanks and used by other employees. The end of a project is the appropriate time to set reasonable standards, to analyze and to apply concrete data that can be drawn on in the planning of future activities. In doing so, successes as well as errors should be analyzed and consistent opportunity and risk management pursued for future projects. The following shows how the post-mortem analysis (PMA) can be used in the risk management of construction projects.

2.8.2. Risk Management in Projects

Risk management includes the integration of risk political principles, the establishment of risk consciousness as well as organizational integration. It is the impetus for the risk management process and is responsible for risk control with knowledge of the current risk situation (Diederichs 2001). Risk management increases transparency; proactive handling can prevent many problems beforehand and the project can be prepared for unavoidable problems. Outcomes can be moderated and the project manager retains control of his project.

Risks that are not recognized can not be evaluated and dealt with. However, complete ascertainment of risks is impossible. It is therefore the task of risk management to ascertain the fundamental risks as completely as possible.

The objective is to describe the risk situation as completely and accurately as possible and to prioritize the risks. For this purpose, the identified risks related to the occurrence probability and the effects on the project are examined. A portfolio and/or risk cost evaluation predominantly serves for classification. Standards must be found based on which individual risks can be evaluated and compared with one another.

A risk must always be described as a loss occurrence to which a total defined value can be assigned. A value for the risk can be calculated from this loss evaluated according to cost and the occurrence probability. The risk evaluation contains the qualitative evaluation and quantitative measurement of individual risks including their multilevel cost and effect relationships. The results of the risk evaluation can help, e.g., to picture a risk portfolio of a project and allow it to be compared with another.

While mathematically and statistically exact methods for risk evaluation are applicable for the banking or insurance industries, these can not be considered the typical risks of the building industry.

Risk control is the active manipulation of the risks determined within the scope of the risk analysis. Measures of risk handling can be either cause or effect related. Cause-related measures should avoid or diminish risks, while effect-related measures serve to reduce or safeguard the amount of loss to be expected in the case of risk (Göcke 2002).

Risk monitoring is the continuous operative control of the effectiveness of the risk control measures. It is not the goal of risk management to completely eliminate risks from the project. Risk monitoring helps to guarantee that the risk position of the project corresponds to the risk situation targeted. This task is supported instrumentally through variance analyses. The internal control system is a component of risk monitoring. The ongoing monitoring of the early indicators takes place by each of the persons responsible and by recurring risk verification.

Measures for control must be taken after the identification, analysis and evaluation of risks. The control process can be subdivided into these subprocesses: designation of the target, designation of the actual, target/actual comparison and variance analysis. Within the scope of the monitoring as permanent process, to see if the implementation of the risk control takes place accordingly. Steps are then to be initiated to determine the causes in discrepancies between an actual and targeted risk situation. The risk strategy must then be adjusted or revised based on these findings. Risk management in projects therefore implies a permanent advancement of the risk management system based on the results of project analyses.

2.8.3. The Post-Mortem Analysis as a Tool for the Identification and Evaluation of Project Risks

The post-mortem analysis serves for the collection of experience in organizations. It enables the identification and processing of experiences in the field of projects.

Details such as uniqueness, lack of standardization, change in project participants and high complexity should particularly be considered within the scope of projects. High complexity leads to the fact that the connections between individual occurrences and the resulting consequences can not be intuitively grasped.

The post-mortem analysis (PMA) should be a structured ritual at the end of every project. Strengths and weaknesses in the project operation are identified in this way. It provides the impetus for the following project; the findings go into the project planning.

In addition, it can help to recognize recurring models in project development that stand in the way of an improvement process. The execution of a post-mortem analysis aids the individual project participants in the development of personal knowledge; learning comes from information.

The processes occurring in the project are the focus of the PMA. Defined processes determine those activities and procedures that are necessary for a common understanding of undisturbed work progress. This involves the collaboration of the project team, the content, the sequence as well as the form and the content of the results of the project acquisition and of the project execution (Palaneeswaran *et al.* 2006). If there are defined processes of the project management in companies that contain quantitative goals and the control associated with it, the risk of failure decreases. At the same time, the performance quality increases with the control and the integration of processes determined by management.

The project review now offers the opportunity to discuss the quality and implementation of existing processes and to identify possible improvements.

The post-mortem analysis must be done via an expert or an expert system. The expert must know the project operations in detail. It must be specified when the post-mortem analysis is conducted and who participated in it when a postmortem analysis is executed.

As a rule, the PMA workshop takes place at defined project milestones or at the end of the project. A moderator leads the procedure; the members of the project team, manager and possible customer representatives are additional participants. The PMA process is made up of five steps:

1. Identifying company success factors. Success factors of the company can be cost and schedule compliance, high performance quality, experienced employees, etc. The goal clarity of improvement measures is sharpened by the examination of the processes in connection with the success factors of the organization.
2. Determining basic conditions. Projects come about under different boundary conditions, demands and influencing variables. The heterogeneous field also has effects on the way in which the PMA can be conducted successfully and efficiently. The goal is to come to the conclusion with minor costs and charges to the employees of the organization unit examined. Therefore, the method of execution of a post-mortem analysis should be adapted to the form of the organization examined. The PMA should be conducted differently depending on the size of a project. In practice, differentiation in small to medium projects with up to 30 project employees and in large projects with over 30 project employees proved to be of value.
3. Designating objective and subjective data. Costs, deadlines and qualities count in the objective data in projects. Subjective data involves, perceived customer satisfaction, communication between the participants, collaboration in the team, personal advancement of the team members, motivation and commitment. Several methods are available for the collection of the data, which are explained in more detail below.
4. Collection of experience. The results of the post-mortem analysis are analyzed. The assessment of the findings can result in a strength/weakness profile. This documents the specific advantages of the project course as well as the detectable deficiencies that either lower the efficiency and safety of the project development, or in the worst case, endanger the project goals.
5. Creation of a catalog of measures. All measures suggested in the strength/weakness profile on the different process themes are brought together in a catalog of measures. The estimated implementation expense and the anticipated implementation length are determined with regard to each individual measure. Priorities are determined for the

measures that are oriented to the success factors of the company. In conclusion, work packages for the improvement of the processes are bundled together when the measures are defined and the need for action is determined. Efficient implementation is important for the success of these measures after conclusion of the post-mortem analysis.

An essential component of the post-mortem analysis is the execution of a workshop on the project history. In the literature, this step is called the most important step in the process (Kerth 2006).

The following methods are used to gain information:

- Interviews;
- Moderated group discussions;
- Questionnaires.

Interviews deliver the first global evaluation of the project success from the view of different groups. As a rule, the practical level and the contact level are analyzed in interviews. Questions on the satisfaction of the contractor organization, on the organization of the client, on the users of the project result and on the project team are at the center. A judgment of the project manager with regard to his technical, administrative and social competency occurs.

The involvement of all hierarchy levels directs the necessary attention to the meaning of especially important processes. A balance between the perception of the management and the perception of the employees can take place in this way.

In addition to the interview with standardized questionnaires, which is especially adapted for large samples, a moderated group discussion can be a better choice with smaller groups. One handicap of group discussion is that opinions are not expressed openly in the group, especially when there is an authority figure or miscellaneous connections exist.

There are different techniques for the implementation of moderated group discussions. In particular, the KJ (Jiro Kawakita) method and Root Cause Analysis are used within the scope of the post-mortem analysis.

The KJ method is named after the Japanese ethnologist, Jiro Kawakita; it is also known by the designation of problem landscape. In the process, a moderator asks the participants to find information on a defined problem and write it up on cards. These cards are then ordered according to similarity in categories and clusters. All cards of a cluster are combined; the team looks for relationships and connections between the clusters. These are substantiated and graphically documented. The result of the KJ method is a deeper understanding of the inner connections of a problem. A search for solution should be directly attached to it.

The Root Cause Analysis, also called Ishikawa Diagram or Fishbone Diagram is used for the systematic identification of problem causes. In this con-

nection, all possible causes producing a certain effect are separated into chief causes and secondary causes (Ishikawa 1984).

Graphic structuring of the causes that enables a clear overall view follows afterwards. In this way, problem causes are identified as completely as possible and their connections graphically represented (see Fig 2.3).

Interviews can be done with the help of questionnaires. The advantage of this is comparability between the projects results.

As a rule, a standardized and structured questionnaire is used for written interview. All persons interviewed receive the same questions presented in structured content sequence. Open questions are particularly suited for a post-mortem analysis, i.e. questions without answer defaults. The assessment of open questions is time-consuming, since the answers must be categorized and combined with similar answer models. However, the aspects in informal discussion that largely elude a written interview can also be explored.

The use of the post-mortem analysis for the assessment of projects in comparison with other methods primarily offers the following advantages (Nelson 2006):

- Identification of structures for the improvement of the process. In principle, the employees reflect on their own methods of operation and at the same time receive feedback from other team members. Connections in projects that have led to problems, so-called risk models, are revealed in this way. The employees also become acquainted with those project management methods that have proven positive in the project. In this way, frequently repeated mistakes and problems can be avoided in future projects.
- Development of the team members. Individual experiences that cannot be captured in written form are shared with the group in open discussion. In addition, the individuals learn from the experiences of the group. Fig 2.4 demonstrates this.

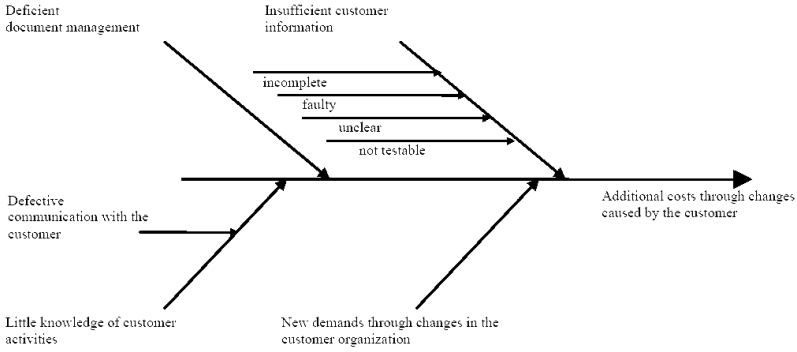

Fig. 2.3. Ishikawa diagram for altered customer demands (Ishikawa 1984)

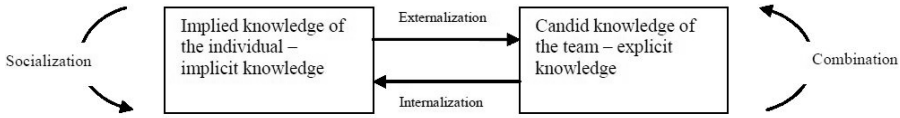

Fig. 2.4. Learning in post-mortem workshops

- Planning of improvement measures. The key risks that threaten the success of the project are uncovered and documented within the scope of the project review. Approaches for improvement and ideas for risk handling frequently result from the comparison of several project retrospectives. Constructive suggestions for future projects are frequently generated in the course of the post-mortem analysis by the better understanding of the team members.

Disadvantages of the post-mortem technique:

- Incomplete project review. The quality of the post-mortem report is dependent on the compilation of the statements of the individual team members. The goal is the most accurate illustration of reality possible. The individual team members do not often have a complete overview of the total project. The only project factors then considered to be important are those that they confront themselves. Or these factors are represented as being more important in order to emphasize their own role in the project.
- Conflicts of interest. This leads to concealment of information. Personal mistakes in the project could be concealed out of anxiety about negative consequences. Conflicts of interest between the project participants are pictured in the postmortem process. On the other hand, mutual interests can balance each other again through the composition of the post-mortem team.
- Grievances in the project are frequently revealed in retrospectives that lead to individual complaints. The criticism of the recipient contained in the complaint, however, can lead to the fact that the person criticized is irritated in such a way, that he no longer participates content-wise in the workshop.

2.8.4. Use of the Post-Mortem Analysis in the Risk Management of Construction Projects

The process in which a structure is drafted, built and used is best described in chronological sequence on the basis of the life cycle of a structure. Buildings of the commercial construction sector, which serve as places of production, commerce or storage, but also as office and administration buildings are at the center of the following observations. The construction process is separated roughly

into three phases – project development, planning and realization phase, as well as the usage phase. At the center of these considerations is realization with the bid and the awarding of the construction work contract, which summarize with the term of construction management. In contrast, many procedures take place at the same time in the planning and realization phase. All necessary plans are prepared by the each of the specialists.

The executive companies create the structure in accordance with these plans. The selection of those participating in the planning frequently takes place within competitions. Different criteria lead to the decision for or against the participants.

Since many procedures occur simultaneously in this phase and different participants work with and side by-side with one another, there is a high coordination cost. In addition to the builder, additional hierarchically organized groups participate in the construction project; architects, building engineers, statisticians, and depending on the particular project, additional specialists must be coordinated in the planning. Different companies from miscellaneous trade groups collaborate again in the execution with the sub-con-tractors selected by you. Different standards of knowledge and goals lead to misunderstandings and conflicts. An error, which emerges in one of the partial stages of the procedure, can lead to delay, and in the worst case, to a standstill of the entire project. Risks in the building industry can be divided into the following types:

- Environmental risks;
- Technical risks;
- Scheduling risks;
- Legal and contractual risks;
- Financial risks;
- Management risks.

There are internal as well as external risks in the process. Internal risks come from the whole structure, from partial buildings and/or the construction process and the participants. External risks are factors that can not be influenced by the project participants or only with great difficulty, since they impact on the structure and/or the construction process from the outside.

At the present time, the possibilities of obtaining information from completed projects are overwhelmingly used with regard to project costs. It is very common in the building industry that cost data banks are established from the project assessment. Since a structuring plan is available with DIN 276, storage of the data ascertained is possible and reproducible, which allows utilization in later projects. Comprehensive key data systems that include more than cost data are very rare in practice. Ascertained project key data can be used not only for the analysis of completed projects, but can also be included in the planning process.

The previously used methods of project assessments in construction projects do not satisfy the demands of integrated risk management. The use of the post-mortem analysis can be an essential tool of risk analysis and in planning new projects. The objective is to improve subsequent projects with the experience gained. Based on the procedure as described, the post-mortem analysis approach is represented in the engineering firm with focus on the performance of the construction management.

1. Success Factors of the Company

The construction manager acts as the responsible person for the quality, costs, and deadline criteria. The qualified employee is at the center of the performance. Project management methods are used for service provision that must be adapted to the respective project data. Communication with the contractor organization is essential. Since large and complex construction projects extend over a longer time frame, change requests and suggestions for improvement frequently arise.

2. Establishing Basic Conditions

A time frame must be defined for the project review and the execution of the project workshop according to the size of the project. The selection of participants plays an important role in the success; it should include the following groups:

- Project management;
- Representatives of the planners;
- Representatives of the specialized planners;
- Representatives of the builder;
- Representatives of the users.

3. Ascertaining Objective and Subjective Data

Objective project data comes from the project cost planning and scheduling. Within the scope of the post-mortem workshop, the above are ascertained with the help of the techniques described above. Possible topic focal points could be: completeness of the planning criteria, planner selection, design, structure functionality, form of contract, contract award process, technique planning, collaboration with the builder, collaboration with the user, collaboration with the executive firms.

4. Collection of Experience

The following illustration represents a section from the results of a workshop for project review (see Fig 2.5). It involved a large project for the producing

trades with very short construction time and high user demand. Members of all participating groups, representatives of the builders and of the users, representatives of the planners, of the project managers and of the construction management were interviewed. The starting points for the subsequent creation of a catalog of measures are detailed strengths/weaknesses profiles. They document the specific advantages of the processes, as well as the detectable deficiencies, inconsistent leading to the endangering of the project goals.

In the existing case, problems arose primarily from the early acquisition of the object by the user, which was not known to the planners and the construction management in this area. In subsequent projects, special attention should also be paid to the schedule planning of the initiation phase as well as the communication with the user to lower the risk to customer satisfaction. The procedure within the scope of cost planning and the transparent data management were seen as positive in the existing project. Therefore, the cost planning tools employed can also be used in subsequent projects in a similar way.

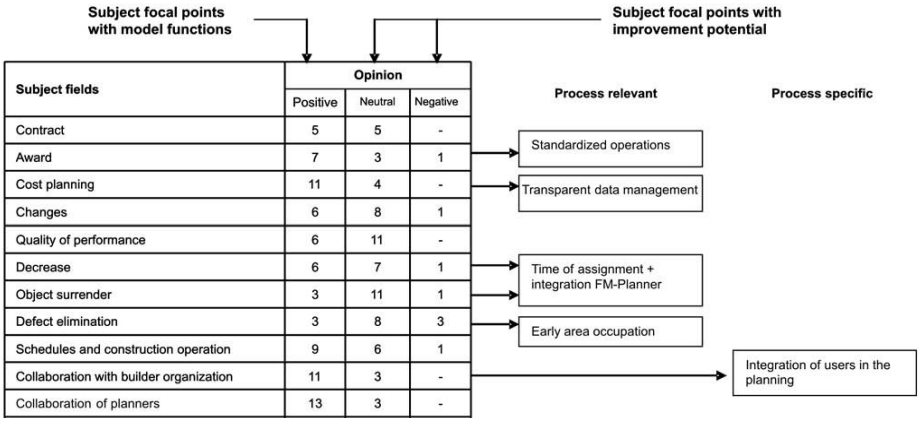

Fig. 2.5. Section from a strengths/weaknesses profile of a large project

5. Creating a Catalog of Measures

All measures suggested within the scope of the strengths/weaknesses profile are brought together into a catalog of measures. The subject areas can be ordered in a portfolio of needed actions according to their optimization requirements. Process topics that urgently require further development can be represented in review form to improve the risk structure of the organization.

As the next step, work packages are bundled for the implementation of the measures in accordance with the measures portfolio. These contain project elements and essential content of the procedure, e.g. personnel, length, steps to be carried out, etc. Tools for risk handling for the future are developed from the

aggregation of the results. These can be check lists, operation guidelines for the project managers, risk costs-databanks, etc. The identification of early warning indicators for risks plays an important role in later projects. Early warning indicators can support risk controlling in the timely identification of relevant changes and emerging goal lapses. So, e.g. a planning delay as a result of delayed plan deliveries can be an indication of impending project changes and thus of a change of the scheduling and financial risk situation.

The post-mortem analysis can be used successfully as an instrument for risk identification and evaluation. A PMA is the identification of process errors and failures. The findings are entered in a risk catalog for future projects. In addition, the post-mortem analysis serves to support learning within the organization. In every project, the team members gain new knowledge and experiences that can be used in future projects. Explicit knowledge of the organization comes from implicit knowledge of the project manager. However, a condition for a successful post-mortem workshop is a corresponding project culture that enables criticism to be expressed positively and also to be accepted positively.

The advancement of the process steps and the deduction of recommendations for upcoming projects follow the compilation and analysis of the problems originated in the project. This increases the quality of the construction management performance in the long-term, and the costs of handling the risk also drop. An efficient risk management system offers the company the opportunity to improve its market position.

2.9. Risks Management in Construction Project Management

2.9.1. Introduction to Risk Management

The economic situation and the expansion of the EU give rise to considerations of how to be able to offer the principal more efficient and more economic offers. This requires a consistent structuring of the enterprise and continuous risk management when carrying out construction projects. Construction projects are exposed to risks at the time of their coming into existence. In various stages, it must first of all be considered what risks the principal would like to counter with measures and how costly these measures are. For this, risks, possible risk costs, measures and costs of the measures must be identified and suitable measures must be found in order to avoid errors in the future. The willingness of the real estate developers to take a risk that causes costs is common to all construction projects. The costs for risks are mostly not allowed for beforehand

and thus reduce its profit margin. Therefore the topic of risk management is worthwhile considering. Hence the attempt to minimize costs due to a failure to take precautions or avoid these completely. Construction projects vary with the course of development, planning, realization and operating. Despite their uniqueness, recurrent processes of these phases can serve as a cornerstone for the recognition of risks in order to consider project-specific and known risks more closely. In this, particular importance is attached to the implementation and realization phase. While in the past claims for damages were regularly presented subject to the precondition that an actual or rather obvious damage or loss at the structure had occurred, in the meantime the claim is increasingly asserted in the case of defects that have not (or not yet) led to damage or loss at structures. The claims for damages, resulting costs and other pecuniary prejudices incurred by the contractor are increasing, e.g. ineffective regulations regarding contractual penalties, errors in the collaboration in the award of the contract, errors in the checking of invoices. Risk management in the architects and engineers office should thus establish itself an essential part of project management.

2.9.2. Definition of Risk

In theory, risk is usually defined as a positive or negative deviation of a variable from its expected value. In general parlance, risk is understood only as a loss. The definition of risk in the meantime not least takes into account the chances. In order to turn risks into chances, the business owner must first know his/her risk sufficiently well. Risk management constitutes a strategy to avoid losses and use available chances or rather chances potentially arising from risks. The strategy demands from the person taking action a precise consideration and assessment of the situation and the scenarios probably occurring in the future. On this basis, decisions are made in the hope of having eliminated all risks and used all chances. This means recognizing potential risks and circumventing a threat by averting, evading or reducing their negative effects.

2.9.3. Risk Management

Risk management in construction projects is of great importance (as shown in Fig 2.6.). Although at the start of a project, through the introduction of risk management, an increased expense is incurred, this is compensated for, in particular through the advantages of risk management. In the planning phase possible risks for the subsequent project success can be identified and reduced through their incorporation into the planning. This has in particular effects on the observance of set dates and deadlines and thus also on the maintenance of the project costs. For the principal, observance of its due date for putting into service an operating unit is of great importance.

The risk potential analysis of a project states to what extent project risks influence the risk situation of the enterprise. Risk potential should be estimated without a detailed consideration of the individual risks at as little expense as possible. Depending on the assessment of the risk potential, the risk management process is set in motion. Risk management comprises the integration of basic principles of risk policy, the establishment of a risk consciousness as well as the organizational integration. It is an impetus for the risk management process and is responsible for the control of risks in full knowledge of the current risk situation (Diederichs 2004). Through risk management, transparency increases, many problems can be avoided from the outset through proactive action, the project can be prepared for unavoidable problems. Through this, the consequences can be mitigated, and the project manager retains the control over his/her project.

The risk management process comprises several steps, which will be explained hereinafter and are represented in Fig 2.7.

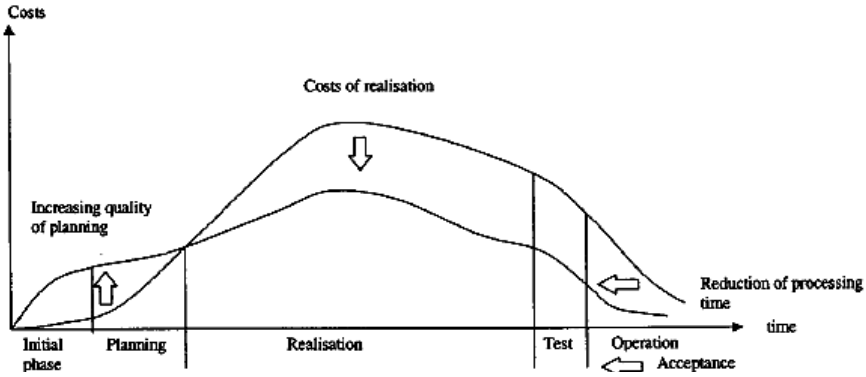

Fig. 2.6. Potential through the use of risk management in construction projects

Fig. 2.7. Elements of risk management

Step 1. Identifying Risks

Risks that are not recognized also cannot be assessed and dealt with. However, a complete coverage of the risks is impossible. The task of risk management is therefore to cover the essential risks as completely as possible. Risk identification must therefore be carried in a way that is both forward-looking and in line with the progress of the project, since before the start of the project not all risks are completely recognizable and during the project implementation further risks may emerge. Fig 2.8 provides an overview of various methods for identifying risks. In principle, creative and guided methods are distinguished. The first type offers the possibility to discover new kinds of risk. Guided methods use such as checklists for identifying risks, with the aid of which the conceivable types of risk are checked. In projects, in particular the following risks occur, which are broken down according to risk types.

Quality risks:
- Defect in interim results;
- Lacking application of project methods;
- Too few controls / tests.

Personnel risks:
- Lack of skills;
- Disagreements in the team.

Cost risks:
- Planning changes;
- Complicated project conditions;
- Customer fails to pay.

Set date/deadline risks:
- No handover in good time;
- The project end is delayed.

Risks of strategic decisions:
- Failure to recognize chances;
- Lack of ability to consistently use chances

External risks:
- Natural occurrences;
- Political changes;
- Changes in society;
- A shift in the market / new markets;
- Legal developments;
- Shifts in sectoral trends;
- Technological changes

Methods for Identifying Risks			
Before the Occurrence		**After the Occurrence**	
Creative Research	**Guided Method**	**Damage**	**Indicators**
Brainstorming	Checklists	Work calculation	Symptomatic indicators
Brain writing	Surveys	Notification of service	Indicators explaining the cause
Synectics	Inspections	Target actual examination	
	Document analysis	Damage report	
	Scenario technique	Balance sheet	

Fig. 2.8. Methods of risk identification (Göcke 2002)

Step 2. Analyzing Risks

The objective is to describe the risk situation as completely and precisely as possible and to prioritize the risks. For this, the identified risks are investigated with regard to the probability of their occurrence and the effect on the project. In the first place, a portfolio and a risk costs assessment respectively serves for classification purposes. Criteria must be found, on the basis of which individual risks can be assessed and compared with one another. A risk must always be described as a damage or loss entailing event to which a particular value can be allocated. From this, damage or loss assessed in terms of costs and the probability of occurrence, a value for the risk can be calculated (Fig. 2.9). Methods of risk assessment are e.g.: an error, possibility and influence analysis. This is a largely formalized analytical method for the systematic coverage of all possible errors and for the estimation of the risks associated with these. In this, within a team, possible potential errors are determined with the aid of a standard error, possibility and influence analysis form, the consequences are investigated and the causes are established and assessed.

Next, the causes of errors are systematically assessed in terms of the probability of their occurrence, the significance for the customer and the probability of their being discovered. Finally, suitable measures are commenced.

The risk portfolio in the risk portfolio risks are ordered according to the amount of damage or loss and the probability of their occurrence. Accordingly, the effects on the project and the need to take action are evaluated. Risk team analysis. The risk evaluation is carried out by the project manager in the context of project controlling. For the risk team analysis, risks are determined and analyzed according to types, and indicators for the occurrence of risk are worked out. From this, possible measures are elaborated and represented and persons responsible for the risk monitoring and notification are determined.

The risk assessment comprises the qualitative assessment and quantitative measurement of individual risks including the interrelationship of their effects. With the help of the results of risk assessment, for example, a risk portfolio of a project can be illustrated and compared with others.

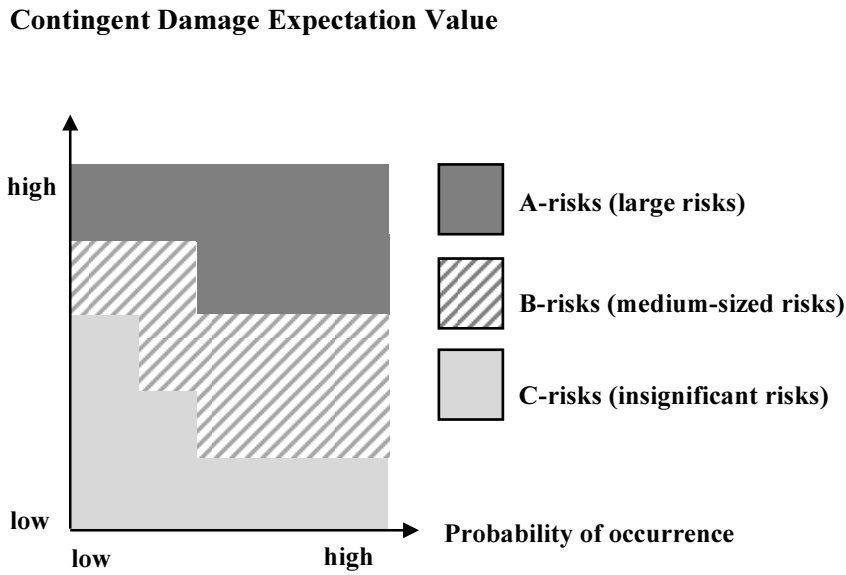

Fig. 2.9. Methods of risk identification (Göcke 2002)

Step 3. Assessing Risks

While for the banking or insurance industry mathematically and statistically exact methods for risk assessment are useful, these cannot satisfy the typical risks in the construction industry. The following methods of risk assessment and risk comparison can also be used in construction projects. Key performance indicators cover quantitatively measurable circumstances and thus create a basis for comparison. They are preferably consulted for risk assessment if a

large number of data and figures must be compared. For the key performance indicators, threshold values from which a risk warning exists are determined. The typical key performance indicators in the real estate sector are average operating costs, average rent, and vacancy rate or average interest on outside capital. Qualitative assessment if no objective data is available, risks must still be quantifiable and made estimable. One of the methods is qualitative estimation and weighting. In this, risks are assessed subjectively according to probability of their occurrence and the amount of damage or loss.

Probable maximum loss. The procedure of quantitative risk determination primarily aims at estimating the probabilities of dangerous occurrences within a risk scenario. In the evaluation of the risk of major damage or loss, for example, the maximum damage or loss possible or probable is determined. ABC analysis The ABC analysis is based on the recognition that frequently a relatively small number of factors make up the largest share of a whole. The goal of the analysis is therefore to find out what factors make up the largest part of the project value and in which a greater planning and control expenditure is justified.

Risk map. The risk map illustrates the risk profile of an enterprise. It is referred to as risk landscape, risk map or risk matrix (Diederichs 2001). In a risk map it can be read with what priority the risks should be approached. In this, the risks that cannot be borne, which could endanger the continued existence of the enterprise, are prioritized. The risk classification in a risk matrix thus enables a differentiated consideration of two classification criteria: probability of occurrence and expected value.

Step 4. Controlling Risks

Controlling risk is the active influencing of the risks determined in the context of the risk analysis. Measures of dealing with risk can be differentiated between cause-related and effect-related measures. Cause-related measures are supposed to avoid or reduce risks, while effect-related measures serve to reduce or safeguard against the amount of damage or loss to be expected in the event of a damage or loss entailing event (Göcke 2002). Strategies of controlling risk are accordingly the following:

- Avoidance;
- Reduction;
- Passing on the risk;
- Bearing the risk by oneself.

Step 5. Monitoring Risks

The monitoring of risks is the continuous operative control of the effectiveness of the risk control measures. The goal of risk management is not to eliminate risks completely from the project. The monitoring of the risk helps guarantee that the risk strived for. This task is supported instrumentally through analyses of variances. The internal control system is part of the monitoring of the risk. The continuous monitoring of the early indicators and the repeated risk verification are carried out by the persons responsible no later than the respective milestone deadlines. A precondition for this is that a reporting and meeting structure in the organization and for the project is stipulated. Besides the pursuit of the risk status and the progress of the measures, new additional risks must be included. Risks that have occurred must be documented with the relevant amount of damage or loss; critical situations of the managerial staff must be reported.

Step 6. Controlling Goals

After the recognition, analysis and assessment of risks, measures for controlling goals must be taken. The control process may be broken down into subprocesses: determination of the target value, determination of the actual value, target/actual comparison and an analysis of variances. As a permanent process, in the context of the monitoring, the risk identification, analysis, and controlling are checked to find out whether the risk control is implemented in due form. In the event of variances between the actual risk situation and the risk situation strived for, steps must be commenced to specify the causes. Based on these recognitions, the risk strategy must then be adapted or revised. Consequently, by monitoring the risk it is guaranteed that standards set of risk management are taken into account.

2.9.4. Risk Management in the Progress of the Project

Responsibility for carrying out the chance and risk management is borne by the project manager. The duty of the project management in the event of risk identification is to discover any emerging risks of a construction project and include these in a risk catalogue. For this, in practice, risk checklists that have been drawn up based on empirical values from comparable construction projects serve as ordinary auxiliary means. From the area of project controlling, in particular the following should be mentioned:

- Plan of services;
- Pursuance of set dates/deadlines and progress;
- Pursuance of costs;
- Quality assurance;

- Analysis of contracts.

In order to encourage willingness to adopt risk management in the construction industry, standard risk checklists should be drawn up, with the help of which the project manager is only required to .tick off. The standard risks occurring. A quick instruction for project managers and teams that is easy to implement should result, which makes it possible to deal more easily with project risks.

The necessity to install a risk management system as early as possible results from the fact that risk potentials exist, at least in a rudimentary form, already before or at the start of the project and are recognizable, however their effects and damage only come to light in the subsequent progress of the project. For this reason, the risk management process should be established and integrated into the entire project process as a permanent (sub-) task of the project management. In this, the identification, analysis and assessment of risks must in each case be geared to the entire project and to special aspects of the individual project phases. In general, the progress of a project can be divided up into three phases:

- Start-up phase;
- Manage phase;
- Close phase.

In this, typical risks occur in the corresponding phases. They must be integrated into the risk management process in order to prevent the progress of the project from being disturbed. For dealing with chances and risks in projects, the following principles apply:

- Responsibility for carrying out the chance and risk management is borne by the project manager;
- Only taking risks that one can influence oneself;
- Avoiding or safeguarding against risks that are influenced by others (customers, subcontractors);
- As far as possible, passing on risks taken;
- The consideration of chances und risks is a part of the project reporting below, with the aid of specific questions characteristic of the individual phases, it is shown where the tasks of risk management integrated into the progress of the project lie. Some questions are stated as examples, in which the type and scope of the questions can be expanded and supplemented at will.

Tasks of Risk Management

Start-up phase (project preparation; planning). The start-up phase corresponds to project steps 1 and 2 from the scope of services of the project control. In the

start-up phase the focus of risk management above all is on the check of the contractual and general circumstances of the project environment. The task of risk management is to recognize possible risks that can disturb the actual progress of the project. Here, risk management should investigate the following typical questions for identifying potential risks:

- Are the project goals clearly defined?
- Does clarity about the project structure exist?
- Have the future planners, advisers and consultants been selected and commissioned?
- Are there specific contractual features?
- Do gaps in services exist in the contracts?
- Is a concept of use available?
- Have the set dates/deadlines for the application for subsidies been complied with?

For the manage phase, the following risk questions are characteristic:

- Are all resources available as planned?
- Does the principal comply with its duties to collaborate?
- Will the principal accept the entire project without serious defects?

Close Phase (Project Completion)

The project end is reached upon the performance of the service and the handover (acceptance) of the structure to the principal (e.g. real estate developer). It becomes particularly critical if the principal refuses to accept the completed solution because the project result is not in accordance with its objectives. Risk management can help avoid such failures by pursuing the questions in the close phase:

- Were the contractual contents and undertakings fulfilled?
- Is a complete project documentation (records of meetings, correspondence, released project documentation etc.)?
- Is the contractually owed service capable of being accepted?

For the further development of the risk management system, it is important that stock is taken of the reflection on the progress of the project. In this, relevant questions are as follows: What identified risks have occurred? What problems that have actually occurred in the progress of the project were not identified as risks and why not?

Risks in the Personnel Sector

Structural upheavals in the world of technology as well as dynamic changes in the sales markets can only be mastered successfully if the employees of an enterprise identify with this and are committed to this. Particularly for enterprises

that offer highly qualified services, specialized employees acting on their own responsibility are essential for market success. For this reason, personnel risk management is necessary in order to not have to accept losses in tactical/operative competence and innovative potential through the departure of employees. Impressionable risk fields can above all be divided up into four areas: Bottleneck risk field, departure risk field, adaptation risk field and motivation risk field (Göcke 2002); these will be explained briefly in the following section.

Bottleneck risk field. This is a matter of identifying in good time in what areas top performers will be absent in the future. In this, the following questions stand in the foreground:

- What are the key qualifications for the future?
- Are strategically important staff positions safeguarded?
- How will the quantitative need for employees change in the future?
- How do the qualitative requirements made of the employees change due to new scopes of service or technologies?

Departure risk field Departures of top performers generally constitute a high risk potential, in particular in long-term projects in which the project manager is the confidante of the real estate developer. Central reasons why employees leave an enterprise are: new challenges, more responsibility for decisions, better professional prospects with regard to career development, and good future perspectives of the new enterprise. The following factors reduce the risk of departure and should therefore be taken into account by the business management: good business climate, favorable outline conditions for employee development, extensive non-material incentives on the part of the enterprise, remuneration structures adequate for the performance, suitable organizational structures and marked allocation of power potentials.

Adaptation risk field falsely qualified employees constitute adaptation risks. Should leaves of absence be avoided, as a precaution requalification or new qualifications are necessary. In construction projects here ongoing further training courses of the employees are necessary with regard to technological and legal changes. In construction project management changed scopes of service must be taken into account through a greater consolidation of services in the implementation of construction work.

Motivation risk field. Diffident services in many cases constitute a significant risk. Burnt-out employees or employees who have resigned in all but name are topical examples. The following behavior all risks are indicative of resignation in all but name:

- An absence of own initiative;
- Over adapted behavior;
- Avoidance of conflicts;

- An absence of constrictive criticism;
- Undertaking less demanding work;
- No longer exhaust existing competences.

Possible instruments for reducing risks in the personnel sector are: Promoting personnel development in a purposeful manner, coaching of managerial staff and employees, forcing identification with the enterprise through a corresponding corporate culture and creating motivation by granting more freedoms and self development.

Effective risk management must permeate all areas, functions and processes of the project. The goal therefore must be to negotiate risks, assess these or even make these marketable and reduce them emphatically. In this, a decisive factor in its success is in the end the interaction of all elements represented.

A risk and control culture borne and experienced by all parties involved in the project has the effect of a connecting bracket that can safeguard the effectiveness of the structural and organizational measures of risk management.

The key to this is the parties involved in risk management. Effective risk management requires commitment as well as the risk conscious behavior of each individual. The motivation as well as the interplay of the parties involved in the project in the end determines the quality of the work and thus the success of the project. Risk management successfully installed in the project offers the chance to gain a clear understanding of the goals, duties and contents of the service and the feasibility of the project. It provides an information basis for the quantitative data, sorted according to size, for the purpose of supporting decisions, such as e.g. the choice between costs and implementing goods or the comparison between several possible options. For this, however, it is necessary that a high quality of the status of information is always available in order to make determinations on the basis of useable and comprehensive information.

Risk management can therefore only be implemented and enforced effectively if communication channels in the enterprise are created, which guarantee the direction of the information to the places concerned in each case.

Through the risk management used, the overall risk of the project is broken down into individual risks. For these, corresponding measures can be taken. Nonetheless, in each project residual risks remain. It remains a strategic decision whether these risks are taken and can be borne if they occur.

2.10. Strategies for Avoiding Asymmetric Information in Construction Project Management

2.10.1. Introduction to Strategies of Information

New forms of competition and contracts have been established on the German construction market; the classical scope of work as described in the HOAI and the clearly regulated payments related to it are becoming less and less important. Construction services are already heading towards a strong orientation to the needs of the clients. These normally don't want to be confronted with a multitude of highly technically specialized engineers but rather look for a qualified advisor for the whole life cycle of their buildings. Services have been offered to that effect like risk management, facility management, and construction management. Clients delegate more and more control and supervisory functions. This development is intensified by the necessity to plan and build in a consumer-oriented, cost-efficient, and quality-conscious way. The great number of persons involved in the construction has to be organized and led by the project management in such a way that the building can be realized according to the targets of the client. When it comes to designing the contract relations, the choice of contractual partners, and the construction controlling it is important to consider that besides the target of constructing a building according to the benefit of the client, the respective actors also want to reach individual benefits. If the participants give their own targets priority over the targets of the client, disturbances in the transformation process may be caused which may result in a reduction of the benefit for the client. This problem is addressed and examined by the Agency Theory which deals with target conflicts and information imbalances. It will be described in short hereafter.

2.10.2. Basic Principles
The Principal Agent Theory within the "Newer Institutions Economics"

In the middle of the last century the discontentment with the neo-classical models of economic science resulted in several new approaches that are summarized under the term "new institutional economics". The consideration of institutional circumstances and their explanation within the economic analysis and the design of institutions that build up on this are in the centre of this field of re-search. This newer institutions economics encompasses especially the Property Rights Approach, the Transaction Costs Theory, and the Agency Theory (Schieg, 2008). In the centre of the present research there are findings on the basis of the Agency Theory, in the course of which principal-agent-relations of all sorts are dealt with. You talk of an Agency Relation when a principal as-

signs to an agent certain tasks and the respective decision competence. The agent chooses one action option from a multitude of options which results in possible effects on him as well as on the principal. The principal is not able to watch the actions of the agent, only the result. But this result depends not only on the actions of the agent but also on external environmental factors. Therefore the principal can not de-duce from the result to the action of the agent. When analyzing the behavior of the agent, it is to be assumed that he will act in a self-serving way. The consequences of this self-serving behavior depend on which restrictions his behavior is subject to. The efficient design of these restrictions, e.g. by legal and contractual regulations, is in the centre of economic organization problems. The core problem of the Agency Relation is the asymmetric information distribution, i.e. the informational advantage of the agent.

Asymmetric Information

The situation in which one of the two co-operation partners is better informed than the other one is described as asymmetric information. Problems resulting from this are economic disadvantages for one of the parties, the inefficient use of resources, and the resulting losses of welfare. The asymmetric information distribution results from hidden action and hidden information. One can act on the assumption that the agent tries to maximize his own benefit even when his individual benefit faces a higher damage on the side of the client (Wenger and Terberger 1988). The information imbalance in co-operations may have effects before as well as after closing a cooperation contract. The term “asymmetric information” describes three information problems which are based on certain coordination and motivation problem: Adverse Selection, Moral Hazard, and Hold-up (Linde 2005). Adverse Selection describes the quality uncertainty of the client with respect to his contractor. The client does not know the qualities or the exact qualification of the contractor before the contract is closed. The contractor might conceal lacking or negative qualities or a very qualified contractor might not tell about his positive qualities. The result would be the choice of undesired contractual partners. Contrary to the Adverse Selection, in the case of Moral Hazard there are information asymmetries that develop after client and contractor are closing the contract. If the client cannot completely supervise the contractor, or if he is not able to deduce stringently the quality of his service from the work result, an information imbalance in favor of the contractor will result. The danger that the agent will exploit this opportunistically is called Moral Hazard. If the client makes large investments because of the co-operation relation and if these investments get lost in case that the contractor acts uncooperatively, a one sided relationship of dependence results from this. The resulting Agency Problem is called Hold-up. The client may afterwards get the information that was held back before but the client then did already make

an irreversible investment. This enables the contractor to confront him e.g. with excessive demands.

Agency Costs

In a world of cost-free information all actors would be completely informed and there would be no coordination or motivation problems. Orders could be commissioned and decisions could be delegated in a way that always the most productive structures of the division of labor and specialization could be realized. In reality, distributed in an incomplete and in most cases unequal way. In Principal Agent Relations lee ways develop which may be exploited to the detriment of the principal. To counteract this, the client will try to reduce the agent's ability to act by means of control mechanisms or by an according design of the contract. This again might foil the advantages in the execution of the order that had been anticipated due to the delegation of decision. This may possibly even cause the effect that the client completely avoids the delegation of decisions fearing adverse behavior of the contractor. The advantage of division of labor and specialization then might not be used due to control problems.

The Agency Costs are made up of three components:

- The signaling costs of the agent;
- The control costs of the principal;
- The remaining loss of welfare.

Signaling costs are all those efforts which the agent himself undertakes to reduce the information asymmetry between him and the principal. Among these are e.g. certificates that proof his qualification, guarantee offers, or securities. Control costs are all efforts of the principal to reduce his information disadvantage. These are quality controls, testing of work probes, or testing of references. If asymmetric information exists, then normally the most efficient distribution of labor possible will not occur. The difference between the productivity in case of optimal information and the actual performance of the agent is called loss of welfare.

Coping with Agency Risks

To cope with Agency Risks, basically three instruments are suggested: establishing target congruity, reducing information asymmetries, and allocation of risks. The harmonization of interests may e.g. be created by a new profit sharing of the agent so the agent will in his own interest yield the performance desired by the principle.

The problems of the Principal Agency Relation may be solved by the following mechanisms:

- Bureaucratic control;

- Information systems;
- Incentives, bonuses;
- Corporate culture;
- Reputation;
- Trust.

Corporate culture plays a special role here. Shared values targets, and competences minimize coordination costs. This facilitates mutual coordination and learning. As mostly new project participants work together in projects, a conscious way of dealing with information asymmetries is of special importance. For the aim of reducing information asymmetries, besides the signaling of the contractor also a monitoring by the client may occur. Formal planning and control systems as well as an integrated reporting can help diminishing information deficits on the side of the client in projects.

Another possibility for the client of gaining information is screening. Screening is the term for all activities by which the principal tries to get more exact information on the quality attributes of the agent that are relevant to him. Among these are work probes, references, certificates, and credit worthiness. Another possibility to avoid Adverse Selection is to construct the contracts in such a way that only desired contractors would sign them because only they would have the self-interest to offer the service under these circumstances. Examples for this are guarantees or a possible loss of reputation for the agent.

2.10.3. Importance of Asymmetrical Information in Construction Project Management Organization of the Construction Project

A construction project is an investment project with fixed targets, results, as well as deadlines and costs. The project management has the task to find an optimal solution for meeting costs, deadlines, and quality. Besides the principal other hierarchically organized groups are involved. During planning, architects, technical suppliers, bearing structure planner, and, depending on the respective project, further specialists, must be coordinated. While executing the project, the different companies from different branches in turn work together with the subcontractors they have chosen. The different states of knowledge and targets lead to misunderstandings and conflicts. A mistake that occurs in one of the sub-steps may lead to a delay and in the worst case to a standstill of the whole project. To cope with the complex tasks of the principal that encompass the coordination, management, and supervision of the construction process in terms of technology, legal issues, and economy, in major projects the performance of project management is commissioned. The project manager here takes over decisions for the client as a line executive. A major task is the choice of the project participants. Among these are the planners, the advisors, and the

assessors. The project manager hereby has to pursue the project targets of the principals' organization:

- The quality of the building;
- The costs of its construction and use;
- The duration of the different steps of the building development;
- The usage potential;
- The risk level which the principal is ready to accept while realizing his other targets.

According to the weighting the principal gives to the respective targets depending on his project, the project management will set up criteria for the choice of the service providers: expertise, willingness to perform, reliability, degree of popularity, image, price, quality, adherence to delivery dates, company is known positively by past orders. Comparable reference objects are of special importance; hereby the quality of the performance is checked by the by means of inquiries at the principals' organization or the project management. The performance of the planners is determined by experience and trust. The quality of their work shows itself only after signing the contract, e.g. by the work equipment used. It is a matter of trust as even after the building is finished the customer cannot really assess to which degree this actually can be attributed to the performance of the individual planner. Prior to the signing of the contract the principal therefore has a problem of choice. He does not have any information about the skills, knowledge, and capabilities of the planners. A wrong choice, e.g. of the architect, may have severe consequences. In cases of concealed quality the Adverse Selection Problem will lead to the principal having to reckon increasingly with architects that are not suited for him and his tasks (Steiner 2004). In a construction project there are networks of Principal Agent Relations that are interwoven. The individual project member is an agent in relation to his client and the principal. But he may also have the role of a principal in relation, e.g. to the executing subcontractor.

Effects of Asymmetric Information on the Project

Adverse Selection. Prior to closing the contract the project manager as a representative of the principal is confronted with the problem of Adverse Selection. He cannot be sure whether the chosen planner meets the qualities stated above to a sufficient degree. An approach to the solution of this problem is overcoming the information asymmetry by Signaling. The market party which is better informed, e.g. the contractor, signals its type to the client who is the worse informed market party, by means of certain signals. In case of Signaling the initiative goes out from the better informed market participants who send out their signals first and who only then get contracts offered by the worse informed market party. Thus, the planner can present his qualities and proof them by

means of certificates or references. The advantages of Signaling must be higher for desired agents than costs of Signaling. At the same time the advantages of Signaling must be lower for undesired agents than their costs of Signaling. If the client undertakes efforts to get to know more about the qualities of the contractor by his own initiative, this is called Screening. In public construction projects therefore VOF-processes are carried out for the choice of construction services. Private principles, too, carry out pre-qualifications. Another possibility to reduce information imbalances is competitions. Above certain defined thresholds the public commissioning of planning services is often carried out by means of VOF-processes in which the qualification of the applying company and its employees is explicitly checked in advance. This pre-qualification of the company helps the bidding authority to judge the suitability for the project envisaged. Still further goes the architecture competition. It sends out signals on three levels, as a qualification control and as a behavior indicator. At first, the principal gets beside the solutions for the task of the competition as the proper target also an insight into the professional abilities and skills of the participating offices, but it also gives information about the creativity and capability of the architects. As only such offices will participate in the competition which will have the confidence that they will win, there is a selection right from the start. The participation in the competition is associated with the risk of high expenditures for the office; risk adverse offices therefore will avoid participation.

Moral Hazard. One major instrument for reducing the risks of Moral Hazard is the harmonization of interests, e.g. by profit sharing of the contractor. For the participants in the planning contractual incentives must be given so that the targets of the principal may be realized. Among these incentives is the exact prognosis of the costs as well as the meeting of these costs by an according planning performance. A contract which leads to cost optimization without reductions of the quality is highly incentive. If the payment is linked to the overall success, it is no longer attractive for the individual project participants to pursue only their own interests. In connection with Moral Hazard the frequency of the cooperation of the project participants is of major importance. If the contractual partners repeatedly cooper-ate with one another this can lead to a reduction of information asymmetries. The mutual trust resulting from long-term cooperation will cause a reduction of risk costs. Besides the harmonization of interests a reduction of the effects of information asymmetry can also be achieved by Monitoring. Formal planning and control systems create more transparency with regard to the actions of the project participants. Here, the competence of the project management installed plays an important role.

Hold-Up. In principle, Hold-up Problems could be solved if it were possible to conclude contracts that are clearly verifiable. But in reality often gaps in the

contract remain which allow the contracting parties to behave in an opportunistic way. Several different forms of cooperation can be differentiated. In this context Spremann speaks of hard and soft designs. Depending on whether the cooperation is linked to clearly formulated, precise regulations, e.g. contractual penalties, profit shares, legal consequences, etc. or whether these conditions are rather for-mal and subjective such as praise, recognition, reputation, etc. Hold-up Problems can also be reduced when a one-sided dependence relation turns into a mutual one. Business relations which are meant to be long-term ones cause the harmonization of interests because the agent thus is more interested to act according to the intentions of the client.

Clarifying the Need for Information in the Project. The need for information that a project participant needs to fulfill his tasks within a certain period of time is defined according to type, quality, and quantity. Here, subjective and objective need for information can be differentiated. The former describes the amount of information that the project participant needs from his subjective point of view on the project while the latter describes the amount of information that is necessary for fulfilling the task. To align these amounts of information and to guarantee the optimal supply of all actually necessary information for the project participants, it is important to define the factors for success of the project in a workshop. Thus, those factors and parameters are identified which are of special importance for the respective participant. Especially in complex and technically challenging projects this will provide each individual project participant with more understanding of those processes that are the most important ones for the success of the project (Picot 1997).

A major factor of success in the project management is to identify during the course of the project, prior to and after signing the contract, those phases in which asymmetric information may disturb the success of the project. While designing the project organization, the interaction of the project participants must be analyzed with respect to lee ways that may be exploited in an opportunistic way. Within the scope of the project management a special focus should be on the design of information duties of the involved partners. When the project management has developed awareness about possible information imbalances, this can be addressed better when designing the flow of information. By means of a suitable reporting system the transparency within the project increases. The use of project communication systems may support the project management in the process of managing the information. Advantages of a project communication system are:

- Responsibilities within the project are transparent for all participants.
- The employee who is responsible in the respective case will be informed automatically by e-mail over the contributions and tasks assigned to him.

- All project contributions are accessible 24 hours a day and thus allow an overview over the current state of the project at any time.
- Information can be recorded, processed and viewed regardless of time.

The more the communication within the project is structured, the easier it is to prevent information asymmetries.

2.11. Performance of Transformational Learning and Redesigning the Manager' Mental and Practical Behavior

Performance of transformational learning and redesigning the manager' mental and practical behavior included six stages (see Fig. 2.10). Once construction managers become aware and conceptualize of their practice-in-use, they can begin the process of changing their practice-in-use to become aligned with their knowledge of worldwide best practice.

If construction manager' activities produce an unsatisfactory result, he changes activities to amend the result. However, if it is impossible to observe the typical situations that led to irrational the result occurring, it is likely that problems will continue to appear. The aim of best practice activities is to redesign construction managers' core patterns of thought and behavior according to their knowledge of worldwide best practice. This is achieved if, after performing the best practice learning process and correcting their mistakes, managers go one step further and ask what the recurring demands and objectives that caused their initial mental and practical behavior are. In redesigning the way managers think that he can become less protective, more open, and gradually more aware. This is the point where individual mental and practical behavior change occurs.

There are quite close relationship between best practice activities and construction managers' learning abilities. Construction managers who shift from best practice learning to best practice activities are able to take on more responsibility and better respond to project, organizational and external environment around them. The managers are able to test potential ideas, solutions, and develop possible alternatives to deal with likely results. Construction managers become more confident in their interpersonal skills and more inspired in problem-solving.

Also it is possible to apply the best practice actions process to construction firms. For contractors to perform better, mistakes that occur should not simply be corrected, as occurs in best practice learning process.

Fig. 2.10. Performance of transformational learning and redesigning the manager' mental and practical behavior

Rather, the underlying framework in the firm that led to the error occurring should be analyzed. In this way, contractors can improve their goals, strategies, plans, technologies, values or beliefs, to improve their overall functionality.

Yeo (2006) examined a Singaporean higher learning institute that was being gradually transformed into a learning organization through the use of reflective-action learning groups. Reflective-action learning groups were intended to provide a specific forum for staff (the members of the firm) to analyze teaching and learning effectiveness in order to improve their skills in these areas.

Blackman and Henderson (2001) compare an organization's knowledge system with a washing machine. In order for clothes to be really clean (which represents attaining new knowledge), all previous dirt (which represents experiences) must be removed. This means that, before a cleansing rinse commences, the dirty water has to be totally drained away. If even a small amount of the previous dirty water remains (representing the ingrained, limiting systems of learning), it will spread through and taint the entire rinse (making it impossible for fresh learning to occur) (Blackman and Henderson 2001).

Transformational learning investigates the context and nature of the learning process itself, and by extension, putting construction manager under the project and organizational scope. Transformational learning involves considering why managers think and act in the manner managers do, and exploring underlying hidden patterns of thinking and acting. Just as best practice actions goes one step further than best practice learning by asking construction managers to examine the internal processes that led to the erroneous behavior occurring, transformational learning goes one step further again, asking construction managers to consider why those particular internal processes even exist, and whether there are other factors operating on a subconscious level to affect con-

struction managers behavior. In a contractor context, transformational learning also involves examining core principles on which the contractor is set, and testing its mission, vision, market position, technology and culture.

Utilizing transformational learning techniques increases construction manager's awareness, helping construction managers gain more control over the factors that affect their behavior, which ultimately helps construction managers to achieve required goals. By observing construction managers language, premises, opinions, responses, and mental models that influence the way managers interact, managers enhance ability to create genuinely new manners of technological, social, ethical, etc. behavior, habits of learning, and improve understanding of how to interact with project, organizational and external environment. This helps construction managers and contractors achieve goals more effectively, as managers become able to identify and remove barriers to goals. Transformational learning can be defined as creation of a setting where conscious collective mindfulness can be maintained. By using transformational learning techniques, individuals can learn to think and act together ways that will benefit the firm.

Blackman and Henderson (2001) claimed that once firms are set in a particular routine, it is very difficult to implement change. The routines tend to perpetuate themselves, making it difficult for employees to extend beyond the ideas and processes already in place. Walsh and Ungson (1991) argue that it is very difficult to erase firms' memory because it is a result of a repeated action (whether appropriate/effective or not), and once the result has been associated with the action, it is defined and fixed as a process within the firm. Blackman and Henderson (2001) note the self-referential nature of learning processes as a barrier to learning: the organization will decide what it considers it needs to know, predetermining the knowledge that employees will then seek, meaning that all knowledge entering the organization is filtered.

Because the routines, filters and self-referential systems are so deeply implanted in the construction firm, best practice actions cannot operate rationally. Because construction managers have become so deep-rooted within the routines and self-referential systems of learning embedded in the firm, construction managers are unable to achieve the higher level of the best practice actions to meaningfully analyze the project, organizational and external environment that led to an error occurring.

Turner *et al.* (2006) conducted research in a British public sector organization with 2800 employees, with a sample of 12 trainees. An initial internal attitude survey showed employees were willing to be involved in a change process in order to enhance their service and working performances. All participants indicated that they were not able to challenge existing assumptions in their workplace. If they did attempt to do so, they felt their position in their work-

place was weakened. Juniors questioning traditional procedures were frightened and marked by managers as trouble makers. This enabled management to keep control over the way things was performed and minimize the opportunities for change.

Possibly the hardest matter for construction managers is to change their mental and practical behavior. As Blackman and Henderson (2001) state it is almost impossible to remove our natural defense mechanisms and embrace new practices and systems of learning, whether individually or in an organizational context. This does not mean change is impossible. Research has identified major factors blocking change, which include managers being afraid of challenges to their authority (Turner *et al.* 2006) and employees being afraid of losing their position as a result of sharing information (Yih-Tong and Scott 2005).

Finally it is can draw a conclusion, that the most important obstacle to knowledge transfer is construction manager's behavior and awareness about future consequences. Managers seek to preserve the comfort zone they have already created. Transformational learning (acquiring new manners of technological, social, ethical, etc. behavior, getting better understanding of how to interact with project, organizational and external environment) and redesigning the behavior can be understood as change of relative perception about the project, organizational and external environment they operate in, which could reduce economic and ethical managers being, social status and psychological comfort zone. To prevent this shake-up from happening, construction managers try to prevent information and knowledge transferring from managers to the firm.

A comfort zone denotes that limited set of behaviors (Bardwick 1995) that a person will engage in without becoming anxious. A comfort zone is a type of mental conditioning that causes a person to create and operate mental boundaries that are not always real. Such boundaries create an unfounded sense of insecurity. For example, inertia is when a person who has established a comfort zone in a particular axis of his/her life, tends to stay within that zone without stepping outside of it. To step outside a person's comfort zone, he/she must experiment with new and different behaviors, and then experience the new and different responses that then occur within his/her environment. The boundaries of a comfort zone can result in an internally rigid state of mind. A comfort zone may alternatively be described by such terms as rigidity, limits or boundaries, or a habit, or even as stigmatized behavior.

The main aim of this research is to help construction managers create a rational project, organizational and external environment for the construction project development by using groupware knowledge. Construction management is shared, purposeful activities based upon the development of common understandings and interpretations of means and ends. Stakeholders generate

the personal and group decisions which contribute to their own success. This article describes the development of the Model for integrated project management based upon multiple criteria decision making theory. The developed Model involves steps that help to determine rational integrated construction management' life cycle by evaluating construction management' life cycle, stakeholders, project, organizational and external environment.

2.12. Concluding Remarks of Chapter 2

1. Therefore, the best integrated project management strategy of another country cannot just be copied. Strategies may only be adapted into a real economic, social, cultural, institutional, technological, technical, cultural, environmental, legal/regulatory and the provisional situation of the existing state. There is no such thing as a single integrated project management strategy to suit all projects and that could be applied to all countries.
2. This model includes:
   a. Knowledge management models and theories can be been applied in the Model for an integrated project management. An original Model for an integrated project management is developed. The research was performed by studying the expertise of advanced industrial economies and by adapting it to Lithuania by taking into consideration its specific history, development level, needs and traditions. A simulation was undertaken to provide insight into creating an effective environment for the Model by choosing rational project, organizational and external factors. The level of efficiency of the integrated project management depends on the many projects, organizational and external variable factors and all these variable factors can be optimized. The main objective of this Model is to analyze the best experiences in the field, to compare it and consequently to present particular recommendations. In this particular case, the construction management development perspectives of Lithuania were analyzed.
   b. Constituent stages (construction project management process, stakeholders involved in the construction, etc.) of the Model were analyzed and described.
3. The Model for an integrated project management was successfully verified in operational conditions.

4. Construction project management as well as the parties involved in the project and the environment having a certain impact on it is described from various perspectives.
5. The suggested systems and subsystems of criteria relating to construction project management and based on economic, technical, technological, organizational, managerial, qualitative, legislative, social and other factors are described in a number of author's publications.

3

Construction Project Management Multiple Criteria Decision Support System

3.1. Complex Systems Theory and Multi-Criteria Decision Making

Real-world complex systems are almost always made up from a large number of interacting components. This leads to complex behavior that is difficult to understand, predict and manage. Research on complex systems is often undertaken by mathematicians, statisticians, engineers, and information and computer scientists (Australian 2009). Many large construction projects are attributed to complex systems. Therefore, accumulation of experience and knowledge, as well as its multiple reuses, in such large construction projects is of particular significance.

At present, the consensus related to one universal definition of complex system does not exist yet (Wikipedia 2009c). Network science seeks to discover common principles, algorithms and tools that govern network behavior (Wikipedia 2009d). Network theory is an area of computer science and network science and part of graph theory. It has application in many disciplines including economics, operations research, and sociology.

Network theory concerns itself with the study of graphs as a representation of either symmetric relations or, more generally, of asymmetric relations between discrete objects (Wikipedia 2009e). Social network analysis maps relationships between individuals in social networks. Such individuals are often persons, but may be groups, organizations, nation states, etc. (Stanley and Faust 1994).

One of Hayek's (1978) main contributions to early complexity theory is his distinction between the human capacity to predict the behavior of simple systems and its capacity to predict the behavior of complex systems through modeling. Hayek (1978) explain that complex phenomena, through modeling, can only allow pattern predictions, compared with the precise predictions that can be made out of non-complex phenomena.

Complexity theory is rooted in Chaos theory. Chaos is sometimes viewed as extremely complicated information, rather than as an absence of order (Hayles 1991). The point is that chaos remains deterministic. With perfect knowledge of the initial conditions and of the context of an action, the course of this action can be predicted in chaos theory.

Complex adaptive systems are special cases of complex systems. They are complex in that they are diverse and made up of multiple interconnected elements and adaptive in that they have the capacity to change and learn from experience. Examples of complex adaptive systems include the stock market, social insect and ant colonies, the biosphere and the ecosystem, the brain and the immune system, the cell and the developing embryo, manufacturing businesses and any human social group-based endeavor in a cultural and social system such as political parties or communities (Wikipedia 2009b).

Complex systems are a scientific field which studies the common properties of systems that are considered fundamentally complex. It is also called complex systems theory, complexity science, and study of complex systems, sciences of complexity, non-equilibrium physics, and historical physics. The key problems of complex systems are difficulties with their formal modeling and simulation. From such perspective, in different research contexts complex systems are defined on the base of their different attributes.

Complex Systems is a new approach to science that studies how relationships between parts give rise to the collective behaviors of a system and how the system interacts and forms relationships with its environment. In a business context, complexity management is the methodology to minimize value-destroying complexity and efficiently control value-adding complexity in a cross-functional approach (Wikipedia 2009c).

Therefore, a method of determining the utility degree and market value of projects is appropriate for the analysis of complex systems. In order to find what price will make project being valuated competitive on the market a

method of determining the utility degree and market value of projects based on the complex analysis of all their benefits and drawbacks is used. According to this method the project‘s utility degree and the market value of project being estimated are directly proportional to the system of the criteria adequately describing them and the values and weights of these criteria.

Since all complex systems have many interconnected components, the science of networks and network theory are important aspects of the study of complex systems. Therefore, a method of multiple criteria multi-variant design of a project life is suitable for the analysis of complex systems. A method of multiple criteria multi-variant design of a project life cycle enabling the user to make computer-aided design of up to 100 000 alternative project versions was developed. Any project life cycle variant obtained in this way is based on quantitative and conceptual information.

3.2. A Construction Project Management Multiple Criteria Decision Support System

Based on the analysis of existing information, expert and decision support systems and in order to determine most efficient versions of construction project management a Construction project management multiple criteria decision support system (CPM-MC-DSS) was developed (Fig. 3.1).

Construction management involves a number of interested parties pursuing various goals as well as having different potentialities, educational level and experience. This leads to various approaches of the above parties to decision making in this field. In order to thoroughly analyze the alternatives available and obtain an efficient compromise solution it is often necessary to define them on the basis of different type of information.

The presentation of information needed for decision making in CPM-MC-DSS may be in conceptual (numerical, textual, graphical, photographical, audio, visual) and quantitative forms.

Thus, quantitative information presentation involves criteria systems and subsystems, units of measurement, values and initial weights fully defining the variants provided. Conceptual information means a conceptual description of the alternative solutions, the criteria and ways of determining their values and weights, etc.

In this way, CPM-MC-DSS enables the decision maker to get various conceptual and quantitative information on construction management from a database and a model-base allowing him to analyze the above factors and make an efficient solution.

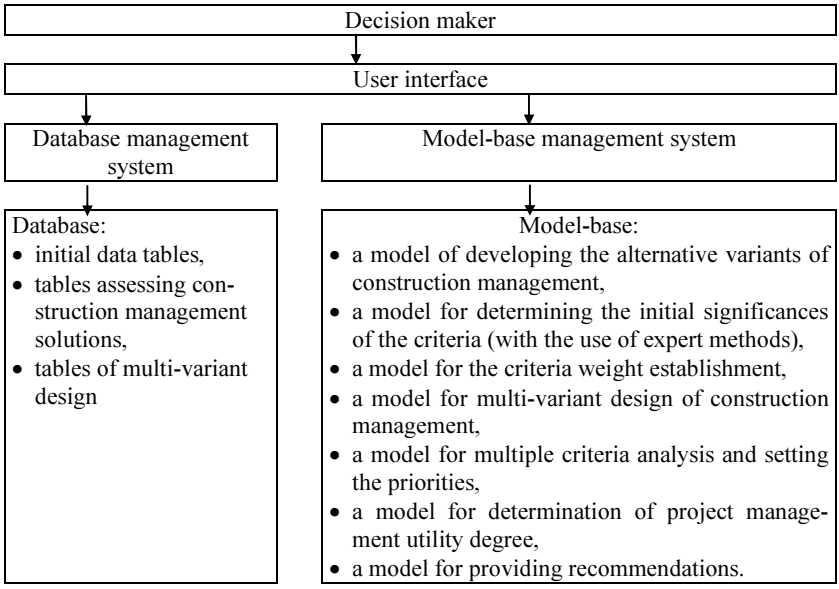

Fig. 3.1. The components of CPM-MC-DSS

The analysis of database structures in decision support systems according to the type of problem solved reveals their various utility. There are three basic types of database structures: hierarchical, network and relational. CPM-MC-DSS has a relational database structure when the information is stored in the form of tables. These tables contain quantitative and conceptual information. Each table is given a name and is saved in the computer external memory as a separate file. Logically linked parts of the table make a relational model. The following tables make CPM-MC-DSS database:

- Initial data tables. These contain general facts about the construction management considered.
- Tables assessing construction management solutions. They contain quantitative and conceptual information about alternative management solutions.
- Tables of multi-variant design. They provide quantitative and conceptual information on the interconnection of the construction management elements, their compatibility and possible combinations as well as data on complex multi-variant design of construction management.

The collection, processing and presentation of information for a database in the computer acceptable form are a complicated time-consuming process. The information collected in a database should be reliable, fully describing construction management as well as enabling CPM-MC-DSS to perform an

efficient multi-variant construction management design and multiple criteria analysis.

To design the structure of a database and perform its completion, storage, editing, navigation, searching, browsing, etc. a database management system was used. Tables of initial data contain the following information:

- General facts about the construction management analyzed;
- Top priority and significances of construction management objectives;
- The amount of money intended for construction management.

It should be noted that various managers making construction management variants and multiple criteria analysis of the same construction often get diverse results. This may be accounted for the diversity of experience, skills, overall aims and financial positions of the managers. Therefore, the initial data provided by various contractors for calculating the construction management project differ, consequently leading to various final results.

The tables of construction management variant assessment contain the variants available and their quantitative and conceptual description. The quantitative description of the alternatives deals with the systems and subsystems of criteria fully defining the variants as well as the units of measurement and values and initial weights. Conceptual description defines the alternatives available in a commonly used language giving the reasons and providing grounds for choosing a particular criterion, calculation its value, significance and the like. The process of drawing up the tables of construction management variant assessment consists of the following steps:

- Collection and presentation of general information about the variants under consideration;
- Establishment and conceptual description of the systems and subsystems of criteria;
- Establishing of criteria for choosing the units of measurement;
- Estimation of the values of the criteria with the description of the process of calculation and its presentation;
- Determination of the initial weights of the criteria with the description of the process of calculation and its presentation.

The information used in compiling the tables of construction management variant assessment has been obtained from the following sources:

- Projects, technical specifications;
- Analogues and similar projects performed;
- Experts, with simultaneous application of expert methods;
- Recommendations, regulations, standards, etc.

Based on various sources of information the variants presenting some interest to the stakeholders as well as some general facts, a system of criteria, their types (quantitative and qualitative), units of measurement and the range of

value estimation are determined. The wider the range of estimating the values and weights of the criteria the more accurate analysis may be done.

The values of the criteria used to describe the alternatives are obtained by analysing the projects as well as using the expert, statistical and other methods, analogies, available recommendations and documents. The accuracy of information about the alternatives presented is of paramount importance, the objective character of the choice of the most efficient variant being largely dependent on it. It should be noted that quantitative information is sufficiently objective. Actual projects have actual costs, time and quality. The values of the qualitative criteria are usually rather subjective though the application of expert methods contributes to their objectivity. The initial weights of all qualitative criteria are obtained by using expert methods. In addition, based on various specifications and standards as well as expertise results and the client's requirements, some limitations on the criteria determining the rejection of the variants from further analysis in case the latter do not satisfy them can be established.

Uniform types of relational tables have been chosen to facilitate entering of appropriate data into the database. Such unified database also make it possible easily correct and introduce new information as well as efficiently carrying out computation. These tables are used as a basis for working out the matrices of decision making. These matrices, along with the use of a model-base and models, make it possible to perform multi-variant design and multiple criteria evaluation of alternative construction management projects resulting in the selection of most beneficial variants.

In order to design and realize an effective construction management project the alternatives available should be analyzed. Computer-aided multi-variant design requires the availability of the tables containing the data on the interconnection of the construction management elements and the solutions made as well as their compatibility, possible combination and multi-variant design.

Since the objectives and financial situations of CPM-MC-DSS users often vary the initial design data and, consequently, the results obtained will also be different. Therefore, the objectives and the financial situation of the clients are expressed quantitatively and provided as the initial data for calculations. These data should be related to the other information of the tables. Based on the above tables of multi-variant design possible construction management variants are being developed. When using a method of multi-variant design until 100 000 alternative construction management projects may be obtained. These project versions are checked for their capacity to meet various requirements. Those which can not satisfy these requirements raised are excluded from further consideration. In designing a number of variants of construction management the problem of significance compatibility of the criteria arises. In this

case, when a complex evaluation of the alternatives is carried out the value of criterion significance is dependent on the overall criteria being assessed as well as on their values and initial weights.

Since the efficiency of a construction management variant is often determined taking into account different factors a model-base of a decision support system should include models enabling a decision maker to do a comprehensive analysis of the variants available and make a proper choice. The following models of model-base are aimed to perform this function:

- A model of developing the alternative variants of construction management;
- A model for determining the initial weights of the criteria (with the use of expert methods);
- A model for the criteria weights establishment;
- A model for multi-variant design of a construction management;
- A model for multiple criteria analysis and setting the priorities;
- A model for determination of a project management utility degree;
- A model for providing recommendations.

Based on the above models, a CPM-MC-DSS can make until 100,000 construction management alternative versions, performing their multiple criteria analysis, determining utility degree and selecting most beneficial variant without human interference.

According to the user's needs, various models may be provided by a model base management system. When a certain model (i.e. determining the initial weights of the criteria) is used, the results of the calculations obtained become the initial data for some other models (i.e. a model for multi-variant design of construction management, a model for multiple criteria analysis and setting the priorities), while the results of the latter, in turn, may be taken as the initial data for some other models (i.e. determining project management utility degree, providing recommendations, etc.). A management system of the CPM-MC-DSS model base provides the user with a model base allowing him to modify the models available, eliminating those which are no longer needed and adding some new models linked with the existing ones.

In order to check the correctness of the suggested CPM-MC-DSS, the whole of its solution process has been more than once gone through manually. The results of manual and computer calculations matched. Besides, all separate working stages of the CPM-MC-DSS as well as all complex calculations have been coordinated with experts in this field, i.e. the essence of the calculations has been found to be in conformity with their logical reasoning. Owing to suggestions of these experts, some useful changes have been introduced into the CPM-MC-DSS. The check-up by the experts is bound with the fact that univer-

sal decision making methods are not always suitable for specific tasks and can lead to gross errors or to bad results altogether.

The more alternative versions are investigated before making a final decision, the greater is the possibility to achieve a more rational end result. Basing oneself on possessed information and the CPM-MC-DSS it is possible to perform the multiple criteria analysis of construction management projects components and select the most efficient versions. After this, the received compatible and rational components of construction management are joined up into construction projects. Having performed multiple criteria analysis of projects made up in such a way, one can select the most efficient ones. Strong and weak points of investigated projects are also given an analysis. Facts of why and by what degree one version is better than the other are also established. All this is done basing on conceptual and quantitative information.

3.3. Case Study: Construction Project Management

One of the families in Berlin is going to build a rational single-family house in the area regarded good for health, rest and treatment. The realization of this task is performed following the purposes of the family, it is necessary to examine these alternatives:

- Single-family houses (4 alternatives);
- Feasible sites for construction (3 alternatives);
- Contractors (2 alternatives);
- Constructability (3 alternatives);
- Types of contracts (4 alternatives);
- Heating systems in buildings (3 alternatives).

During the undertaken computer-aided analysis there were examined 4 alternatives of single-family houses and 3 construction sites (Lithuanian resorts in Palanga and Druskininkai, plus Aalborg in Denmark). The analysis made had been based on the initial data and data base.

The efficiency level of the considered house depends on a great many of factors, including: geographical situation and local orientation (in respect of the sea or some other water body) of the acquired place or area, its distance from the pollution sources and their polluting intensity, infrastructure of the settlement, the service network, cost of living, the amount of commuting expenditure, etc. The purchase price of building plots in the three alternatives also differs.

There have been examined three alternatives of heating systems-centralized, from the network, and local, when coal and gas is used for heating premises. From the point of view of ecology, heating by coal causes the great-

est harm. Each of these three heating systems can function by means of three alternatives. They are as follows:

- Air heating;
- Heating system having an automated temperature control;
- Air conditioning (air temperature and humidity control).

The computing results have revealed that the level of comfort in premises and ease control of heating and ventilation systems is not proportionate to the operating expenditure and estimated costs.

Usually users after some acquaintance with the new equipment giving them considerable comfort tend to get disappointed about the installed heating and ventilation systems because of their sophisticated operation. In qualities that case, priority is given to traditional ordinary heating systems even though it entails a lot of inconvenience and discomfort. This psychological aspect should not be disregarded.

Formation of feasible alternatives of projects is based on the data base of criteria characterizing processes (solutions), feasible interchangeable processes (solutions). This procedure allows developing up to 100 000 project alternatives and getting matrices of very large values of criteria. Therefore, the number of alternatives being investigated should be reduced. This is achieved by the use of two methods sifting irrational alternatives from the rest. Selection of the best suitable alternatives out of a great number of alternative solutions is the basic function of both methods for sifting alternatives (see Section 3.1).

The initial quantitative and qualitative databases (criteria system, values and weights of criteria) of construction sites, buildings, walls, heating systems, contractors, constructability and contracts was compiled from the information provided by experts and managers.

The twenty eight construction project management experts and managers were asked to select the criteria, which correspond in the best way to the development of construction project management. Semi-structured and open-ended question interviews were used as the means for questioning a diverse group of experts and managers and to describe their expectations and experiences during their assessment of construction project management. Twenty-eight persons took part in face-to-face interviews: four interviews with couples and twenty with individuals were completed. To maximize the range of possible experiences and opinions, we included persons of diverse ethnicity, educational levels and age. After questioning the respondents and processing the obtained results by using an expert's method, the concrete systems of criteria characterizing the efficiency of construction project management were identified. We shall proceed with a brief analysis of the criteria systems extensively describing constructability programs, contracts and contractors as an example.

The factors have been considered in constructability program alternatives under analysis included the following criteria:

- Managing the project;
- Project delivery system;
- Contracting strategy;
- Risk management;
- Work package breakdown;
- Labor plan;
- Access to site: size of equipment, weather restraints and urban restrictions;
- Site layout;
- Access to install and replace large equipment within the structure;
- Sequence of construction;
- Rigging plan;
- Availability and procurement of long lead time equipment and materials;
- Prefabrication;
- Preassembly;
- Modularization;
- Construction management organization plan;
- Quality management; materials management;
- Site facilities (offices, temporary power, water, sewer, security, roads, parking, lay-down, etc.);
- Safety;
- Operability;
- Maintainability.

Factors that affected selection of the type of contract alternatives included the following criteria:

- Owner's corporate policy on contracting;
- Availability of in-house experienced personnel;
- Time available to get the project designed and constructed;
- Desire of owner to control elements of project;
- Importance of cost to owner;
- Amount of risk owner wants to contract out;
- Availability of contractors;
- Local construction climate;
- Experience or confidence in contractor or design builder;
- Pre-contract period (long, short);
- Consultants (chosen by contractor or employer);
- Sub-contractors (domestic, nominated);

- Valuations of variations (expensive, cheap, at cost);
- Completion (fixed, controlled, at large).

The competitions for the actual contract have been organized taking into account a set of criteria, reflecting the objectives to be attained:

- Estimated cost of Project;
- Quality of final building product;
- Duration of construction;
- Financial strength of building firm;
- Reliability of building firm;
- Organization and management capabilities;
- Ability to formulate practical programs;
- Ability to maintain program;
- Standard of workmanship;
- Site organization;
- Conduct of labor relations;
- Relations with sub-contractors and statutory authorities;
- Attention to site welfare and safety;
- Degree of co-operation;
- Appropriateness of organizational structure;
- Effectiveness of communication;
- Flexibility of management;
- Motivation of the team;
- Experience of the team;
- Did rely extensively on sub-contractors?
- Were there any problems with payments to sub-contractors and suppliers?
- Were defects remedied promptly?
- Were final accounts settled satisfactory?

According to the suggested methodology, execution of the lifetime alternatives of a building and multiple criteria evaluation as well as selection of the best suitable alternatives from the other alternative solutions can be fulfilled in two stages. In the 1st stage the best suitable solutions (processes) are determined. In the 2nd stage the lifetime alternative projects of a building multiple criteria evaluation as well as selection of the best alternatives is carried out.

Thus, at first we will examine briefly the multiple criteria analysis of separate processes and solutions illustrating it by an example of a single-family house evaluation.

The analysis of database structures in decision support systems according to the type of problem reveals their various levels of utility. There are three basic types of database structures: hierarchical, network and relational. The MDSS-CPM system has a relational database structure when the information is

stored in the form of tables. These tables contain quantitative and conceptual information. Each table is given a name and is saved in the computer external memory as a separate file. Logically linked parts of the table form a relational model.

As an example of a multiple criteria analysis, we will take the case of selection of a rational single-family house (Fig. 3.4). After clicking the mouse on the items “Description of the alternatives” and “Buildings” the System provides the user with the initial data necessary for the analysis. The main data on the compared variants are presented in the form of a decision-making matrix, where columns express the discussed alternative variants of buildings; and quantitative information is presented in rows, which describe the discussed alternatives in detail. In this particular case, four variants of buildings are presented for further analysis, and are described by 18 criteria in detail.

Solutions considered

Please select solution under consideration

Buildings

Qualitative and quantitative description of the alternatives

Quantitative and qualitative information pertinent to alternatives							
Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives			
				House 1	House 2	House 3	House 4
Estimated costs	-	Eur	0,348	146000	175000	162000	179000
Equivalent fuel needed for heating premises	-	T/Year	0,651	3,8	4,3	3	4
Conveniences to use a heating system	+	Points	0,0209	0,5	0,5	0,5	0,5
Lasting of a building	+	Points	0,1965	1	1	1	1
Roof covering	+	Points	0,0073	0,9	0,9	0,9	0,9
General comfort	+	Points	0,0707	0,6	0,7	1	0,6
General functional convenience	+	Points	0,0429	0,7	0,8	1	0,7
Volumetric proportionality of premises	+	Points	0,0282	0,5	1	1	0,6
Living area	+	m2	0,0624	120	142	188	201
Floor height	+	Points	0,0585	0,8	0,9	0,9	0,8
Class of a building according to its type	+	Points	0,0084	1	1	1	1
Garage influence	+	Points	0,0066	0,2	0,2	0,2	0,2
Evaluation of aesthetic qualities of the exterior	+	Points	0,0272	0,8	1	1	0,8
Evaluation of the external finish	+	Points	0,016	0,8	1	1	0,8
Evaluation of materials harmful to health	+	Points	0,046	0,8	0,8	0,8	0,8
Evaluation of balconies and loggias	+	Points	0,0031	0,3	0,3	0,3	0,3
Evaluation of the number of rooms	+	Points	0,0098	0,8	0,4	1	1
Evaluation of characteristics of sound isolation	+	Points	0,0272	1	0,9	1	0,9

Fig. 3.2. Initial data for a multiple criteria analysis

Fig. 3.3. Photos of analyzed houses

Quantitative and qualitative information pertinent to alternatives							
Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives			
				House 1	House 2	House 3	House 4
Estimated costs	-	Eur	0,348	0,0767	0,092	0,0852	0,0941
Equivalent fuel needed for heating premises	-	T/Year	0,651	0,1638	0,1854	0,1293	0,1725
Conveniences to use a heating system	+	Points	0,0209	0,0052	0,0052	0,0052	0,0052
Lasting of a building	+	Points	0,1965	0,0491	0,0491	0,0491	0,0491
Roof covering	+	Points	0,0073	0,0018	0,0018	0,0018	0,0018
General comfort	+	Points	0,0707	0,0146	0,0171	0,0244	0,0146
General functional convenience	+	Points	0,0429	0,0094	0,0107	0,0134	0,0094
Volumetric proportionality of premises	+	Points	0,0282	0,0045	0,0091	0,0091	0,0055
Living area	+	m2	0,0624	0,0115	0,0136	0,018	0,0193
Floor height	+	Points	0,0585	0,0138	0,0155	0,0155	0,0138
Class of a building according to its type	+	Points	0,0084	0,0021	0,0021	0,0021	0,0021
Garage influence	+	Points	0,0066	0,0016	0,0016	0,0016	0,0016
Evaluation of aesthetic qualities of the exterior	+	Points	0,0272	0,006	0,0076	0,0076	0,006
Evaluation of the external finish	+	Points	0,016	0,0036	0,0044	0,0044	0,0036
Evaluation of materials harmful to health	+	Points	0,046	0,0115	0,0115	0,0115	0,0115
Evaluation of balconies and loggias	+	Points	0,0031	0,0008	0,0008	0,0008	0,0008
Evaluation of the number of rooms	+	Points	0,0098	0,0024	0,0012	0,0031	0,0031
Evaluation of characteristics of sound isolation	+	Points	0,0272	0,0072	0,0064	0,0072	0,0064
The sums of weighted normalized maximizing (projects 'pluses') indices of the alternative				0,1451	0,1577	0,1748	0,1538
The sums of weighted normalized minimizing (projects 'minuses') indices of the alternative				0,2405	0,2774	0,2145	0,2666
Significance of the alternative				0,3924	0,3885	0,4562	0,3855
Priority of the alternative				2	3	1	4
Utility degree of the alternative (%)				86,01%	85,15%	99,99%	84,49%

Fig. 3.4. Multiple criteria evaluation and determination of the utility degree of single-family houses*

Figure 3.2 presents the criteria system, criteria measuring units, and values and weights, which describe the discussed alternatives of buildings in detail. A user may review all criteria, their values and significances.

A mouse-click on the title of each discussed variant opens a new window on the web-browser, which presents detailed conceptual (textual, photographic) data of the selected variant. When a user activates a particular item, he/she may review additional textual and photographic information on each alternative. The relation of various types of weights shows the number of times a particular criterion has greater/smaller influence on complex effectiveness of alternatives.

*Sign +/– indicates that a greater/lesser criterion value corresponds to its significance for a client.

Approximation cycle	The corrected value	It is determined whether the corrected value being valuated had been calculated accurately enough
0	179000	7,54%
1	165500	2,04%
2	162125	0,52%

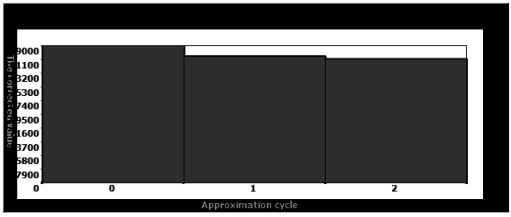

Fig. 3.5. Determination of market value the houses number 4 under consideration

In the above case, the alternatives of single-family houses were evaluated according to the following criteria groups:

- Construction process: estimated costs, construction duration;
- Criteria expressing the operation process and living comfort (thermal and sound isolation qualities in a building; evaluation of the exterior of a building in terms of aesthetics; general comfort of a building and its functional convenience; dimensional proportionality of premises; living and technical areas; materials used for building; evaluation of detriments to health; lasting of a building; upkeep costs).

The multiple criteria analysis of alternative buildings is based on the initial data shown in Figure 3.2. It is seen from its Figure 3.2 that each alternative has it own strengths and weaknesses.

The effect of materials detrimental to health, general comfort for living in the building, its functional convenience, dimensional proportionality of premises, and other qualitative characteristics are rated by points. The higher is the value of the point, the better is the solution. The physical sense of a specific criterion rated in points rests on the fact that it indicates how many times the value of one alternative criterion is more significant for man than the value of the corresponding criterion of another alternative.

In practice, the values of qualitative characteristics are expressed in points. The way they are determined is as follows:

- The best suitable alternative is chosen according to a specific criterion.
- The considered criterion of the selected best alternative is set equal to the magnitude of one point.

- The ratio amongst the best criterion magnitude and all the rest alternatives of the corresponding criterion magnitudes is determined.
- The criteria are given relative values.

esults of Multiple Criteria Evaluetion

Constructability

Quantitative and qualitative information pertinent to alternatives						
Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives		
				Constructability type 1	Constructability type 2	Constructability type 3
Managing the project	+	Points	0,7	0,2435 AVG MIN	0,2739 AVG MIN	0,1826 AVG MIN
Project delivery system	+	Points	0,5	0,1522 AVG MIN	0,1957 AVG MIN	0,1522 AVG MIN
Contracting strategy	+	Points	0,6	0,1579 AVG MIN	0,2842 AVG MIN	0,1579 AVG MIN
Risk management	-	Points	0,7	0,28 AVG MIN	0,21 AVG MIN	0,21 AVG MIN
Work package breakdown	+	Points	0,4	0,1333 AVG MIN	0,1333 AVG MIN	0,1333 AVG MIN
Labor plan	+	Points	0,4	0,1143 AVG MIN	0,1524 AVG MIN	0,1333 AVG MIN
Access to site: size of equipment, weather restraints and urban restrictions	+	Points	0,6	0,1875 AVG MIN	0,1875 AVG MIN	0,225 AVG MIN
Site layout	+	Points	0,5	0,1905 AVG MIN	0,1429 AVG MIN	0,1667 AVG MIN
Access to install and replace large equipment within the structure	+	Points	0,2	0,0933 AVG MIN	0,0533 AVG MIN	0,0533 AVG MIN
Sequence of construction	+	Points	0,15	0,0614 AVG MIN	0,0545 AVG MIN	0,0341 AVG MIN
Rigging plan	+	Points	0,3	0,0955 AVG MIN	0,0955 AVG MIN	0,1091 AVG MIN
Availability and procurement of long lead time equipment and materials	+	Points	0,6	0,225 AVG MIN	0,225 AVG MIN	0,15 AVG MIN
Prefabrication	+	Points	0,5	0,1944 AVG MIN	0,1944 AVG MIN	0,1111 AVG MIN
Preassembly	+	Points	0,2	0,0889 AVG MIN	0,0556 AVG MIN	0,0556 AVG MIN
Modularization	+	Points	0,4	0,14 AVG MIN	0,14 AVG MIN	0,12 AVG MIN
Construction management organization plan	+	Points	0,6	0,1909 AVG MIN	0,2182 AVG MIN	0,1909 AVG MIN
Quality management; -materials management	+	Points	0,6	0,2077 AVG MIN	0,2077 AVG MIN	0,1846 AVG MIN
Site facilities (offices, temporary power, water, sewer, security, roads, parking, laydown, etc.)	+	Points	0,4	0,1333 AVG MIN	0,0889 AVG MIN	0,1778 AVG MIN
Safety	+	Points	0,8	0,2545 AVG MIN	0,2182 AVG MIN	0,3273 AVG MIN
Operability	+	Points	0,9	0,3273 AVG MIN	0,2864 AVG MIN	0,2864 AVG MIN
Maintainability	+	Points	0,5	0,1875 AVG MIN	0,1458 AVG MIN	0,1667 AVG MIN
The sums of weighted normalized maximizing (projects 'pluses') indices of the alternative				3,3789	3,3534	3,1179
The sums of weighted normalized minimizing (projects 'minuses') indices of the alternative				0,28	0,21	0,21
Significance of the alternative				3,608	3,6207	3,3724
Priority of the alternative				2	1	3
Utility degree of the alternative (%)				99,65%	100%	93,14%

*- The sign "+" indicates that a greater (less) criterion value corresponds to a greater significance for a user (stakeholders)

Fig. 3.6. Multiple criteria analysis of constructability

In order to illustrate it visually, let us compare the 3rd project with the 4th one (see Fig. 3.2). The construction of the house according to the 4th design gave rise to enlargement of the living area. But in building project 3 better qualitative results (general comfort and functional convenience, ratio of volumetric proportions of premises, effective area, floor height, evaluation of aes-

thetic qualities of the exterior and external finish, sound isolation characteristics of constructions) had been obtained. In addition, the house required less fuel for heating. As can be seen from Figure 3.2, each criterion goes together with its measurement unit and significance. The magnitude of significance indicates how many times one criterion is more significant than the other one in a multiple criteria evaluation of projects. After determining the utility degree of the projects, market value was defined (Figure 3.5). In order to find what price will make the alternatives being valuated competitive on the market a method of determining the utility degree and market value of objects based on the complex analysis of all their benefits and drawbacks was used by the author. According to this method the alternatives utility degree and the market value of alternatives being estimated are directly proportional to the system of the criteria adequately describing them and the values and significances of these criteria.

The criteria characterizing other alternative solutions and processes were stored in a computer system in the same way. Then, the multiple criteria evaluation of the other processes (solutions) including feasible locations of construction sites, walls, heating systems, contractors (see Fig. 3.7), constructability (see Fig. 3.6) and contracts (see Figure 3.8) was executed in quite the same way as it had been done previously when evaluating the buildings.

The multiple criteria analysis enabled selecting the best alternative designs of processes (solutions). The processes of evaluation and selection of the best alternatives passed in the same way as in the case when selecting the most appropriate alternatives according to the principle of multiple criteria evaluation. In order to illustrate it visually, the results obtained by multiple criteria evaluation of feasible construction locations are presented in Figure 3.2. Figure 3.3 deals with the corresponding results of heating systems.

Figure 3.4 shows the evaluation results of two Lithuanian construction firms carrying out construction work within the country. The selection of the best firm is based on the optimal results.

From Figure 3.5 is seen by what percentage the terms offered by the selected best construction firm are better than those offered by another construction firm (costs, duration of construction as well as other criteria were established by the previous practice of construction work).

After a multiple criteria analysis of construction sites, buildings, walls, heating systems, contractors (see Fig. 3.7), constructability (see Fig. 3.6) and contracts (see Fig. 3.8), alternative variants are developed in an automated way (see Fig. 3.5); and the best alternative combinations are provided (see Fig. 3.9).

After the activation of the item “Multiple criteria analysis of the developed alternatives” the multiple criteria analysis of the developed construction project management feasible alternatives is performed (see Fig. 3.10).

esults of Multiple Criteria Evaluetion

Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives	
				Contractor 1	Contractor 2
Estimated cost of project	-	Eur	1,3	0,6757 AVG MIN	0,6243 AVG MIN
Quality of final building product	+	Points	0,651	0,353 AVG MIN	0,298 AVG MIN
Duration of construction	-	Month	0,109	0,053 AVG MIN	0,056 AVG MIN
Financial strength of building firm	+	Points	0,081	0,0405 AVG MIN	0,0405 AVG MIN
Reliability of building firm	+	Points	0,065	0,0381 AVG MIN	0,0289 AVG MIN
Correspondence of the type of contract to requirements of client	+	Points	0,209	0,1017 AVG MIN	0,1073 AVG MIN
Correspondence of the type of contract to requirements of contractor	+	Points	0,065	0,0381 AVG MIN	0,0289 AVG MIN
Organisation and management capabilities	+	Points	0,034	0,018 AVG MIN	0,016 AVG MIN
Ability to formulate practical programmes	+	Points	0,033	0,0165 AVG MIN	0,0165 AVG MIN
Ability to maintain programme	+	Points	0,035	0,0175 AVG MIN	0,0175 AVG MIN
Standard of workmanship	+	Points	0,052	0,026 AVG MIN	0,026 AVG MIN
Site organization	+	Points	0,02	0,0086 AVG MIN	0,0114 AVG MIN
Conduct of labour relations	+	Points	0,033	0,0175 AVG MIN	0,0155 AVG MIN
Relations with su-contractors and statutory authorities	+	Points	0,021	0,0098 AVG MIN	0,0112 AVG MIN
Degree of co-operation	+	Points	0,02	0,0095 AVG MIN	0,0105 AVG MIN
Appropriateness of organisational structure	+	Points	0,03	0,014 AVG MIN	0,016 AVG MIN
Effectiveness of communication	+	Points	0,034	0,0189 AVG MIN	0,0151 AVG MIN
Flexibility of management	+	Points	0,023	0,0123 AVG MIN	0,0107 AVG MIN
Motivation of the team	+	Points	0,05	0,0233 AVG MIN	0,0267 AVG MIN
Experience of the team	+	Points	0,051	0,0272 AVG MIN	0,0238 AVG MIN
Did rely extensively on sub-contractors?	+	Points	0,023	0,0107 AVG MIN	0,0123 AVG MIN
Were there any problems with payments to subcontractors?	-	Points	0,04	0,0212 AVG MIN	0,0188 AVG MIN
Were defects remedied promptly?	+	Points	0,044	0,0235 AVG MIN	0,0205 AVG MIN
Were final accounts settled satisfactory	+	Points	0,042	0,021 AVG MIN	0,021 AVG MIN
The sums of weighted normalized maximizing (projects "pluses") indices of the alternative				0,8417	0,7743
The sums of weighted normalized minimizing (projects "minuses") indices of the alternative				0,7499	0,6991
Significance of the alternative				1,5653	1,5242
Priority of the alternative				1	2
Utility degree of the alternative (%)				100%	97,37%

Fig. 3.7. Multiple criteria evaluation and determination of the utility degree of contractors

esults of Multiple Criteria Evaluetion

Results of multiple criteria evaluation of the alternatives

Please select solution under consideration

Types of Contracts

Quantitative and qualitative information pertinent to alternatives							
Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives			
				Contract type 1	Contract type 2	Contract type 3	Contract type 4
owner's corporate policy on contracting	+	Points	0,9	0,1969 AVG MIN	0,225 AVG MIN	0,225 AVG MIN	0,2531 AVG MIN
availability of in-house experienced personnel	+	Points	0,6	0,1448 AVG MIN	0,1448 AVG MIN	0,1241 AVG MIN	0,1862 AVG MIN
time available to get the project designed and constructed	+	Points	0,8	0,2154 AVG MIN	0,1846 AVG MIN	0,2462 AVG MIN	0,1538 AVG MIN
desire of owner to control elements of project	+	Points	0,5	0,1111 AVG MIN	0,1481 AVG MIN	0,1667 AVG MIN	0,0741 AVG MIN
importance of cost to owner	+	Points	1	0,25 AVG MIN	0,25 AVG MIN	0,25 AVG MIN	0,25 AVG MIN
amount of risk owner wants to contract out	+	Points	0,6	0,1448 AVG MIN	0,1655 AVG MIN	0,1034 AVG MIN	0,1862 AVG MIN
availability of contractors	+	Points	0,8	0,1455 AVG MIN	0,2545 AVG MIN	0,2909 AVG MIN	0,1091 AVG MIN
local construction climate	+	Points	0,5	0,125 AVG MIN	0,1042 AVG MIN	0,1458 AVG MIN	0,125 AVG MIN
experience or confidence in contractor or design builder	+	Points	0,7	0,1697 AVG MIN	0,1697 AVG MIN	0,1697 AVG MIN	0,1909 AVG MIN
pre-contract period (long, short)	+	Points	0,6	0,125 AVG MIN	0,15 AVG MIN	0,125 AVG MIN	0,2 AVG MIN
consultants (chosen by contractor or employer)	+	Points	0,2	0,0273 AVG MIN	0,0455 AVG MIN	0,0545 AVG MIN	0,0727 AVG MIN
sub-contractors (domestic, nominated)	-	Points	0,6	0,1846 AVG MIN	0,2308 AVG MIN	0,1385 AVG MIN	0,0462 AVG MIN
valuations of variations (expensive, cheap, at cost)	-	Points	0,7	0,14 AVG MIN	0,196 AVG MIN	0,224 AVG MIN	0,14 AVG MIN
completion (fixed, controlled, at large)	+	Points	0,6	0,12 AVG MIN	0,16 AVG MIN	0,14 AVG MIN	0,18 AVG MIN
The sums of weighted normalized maximizing (projects 'pluses') indices of the alternative				1,7755	2,0019	2,0413	1,9811
The sums of weighted normalized minimizing (projects 'minuses') indices of the alternative				0,3246	0,4268	0,3625	0,1862
Significance of the alternative				2,0706	2,2617	2,3436	2,4963
Priority of the alternative				4	3	2	1
Utility degree of the alternative (%)				82,95%	90,6%	93,88%	100%

* – The sign "*" indicates that a greater (less) criterion value corresponds to a great significance for a user (stakeholders)

Fig. 3.8. Multiple criteria analysis of contracts

The Recommendation Module of the MDSS-CPM system analyses criteria, which affect the market value of alternatives, and their values; it also gives recommendations. Formalized presentation of a multiple criteria analysis (see Fig. 3.9) shows how changes in the criteria and the extent to which the goals pursued by various interested parties are satisfied cause corresponding changes in the value and the utility degree of the alternatives.

With this in mind, it is possible to solve the problem of optimization concerning satisfaction of the needs at reasonable expenditures. This requires the analysis of criteria allowing to find an optimal combination of different interested parties' goals pursued and finances available. As example, Figure 3.11 provides extensive information about the quantitative effect of criteria on market value of building. Each cell of this table shows three numbers:

- The numerical value of the analyzed criterion;
- Possible improvement of the analyzed criterion in %;

- Possible increase of the market value of the alternative in % through increased value of the aforementioned criterion.

Safety	+	Points	0,8	7	7	7	7	6	6	6	6	9	9
Operability	+	Points	0,9	8	8	8	8	7	7	7	7	7	7
Maintainability	+	Points	0,5	9	9	9	9	7	7	7	7	8	8
owner's corporate policy on contracting	+	Points	0,9	7	8	8	9	7	8	8	9	7	8
availability of in-house experienced personnel	+	Points	0,6	7	7	6	9	7	7	6	9	7	7
time available to get the project designed and constructed	+	Points	0,8	7	6	8	5	7	6	8	5	7	6
desire of owner to control elements of project	+	Points	0,5	6	8	9	4	6	8	9	4	6	8
importance of cost to owner	+	Points	1	9	9	9	9	9	9	9	9	9	9
amount of risk owner wants to contract out	+	Points	0,6	7	8	5	9	7	8	5	9	7	8
availability of contractors	+	Points	0,8	4	7	8	3	4	7	8	3	4	7
local construction climate	+	Points	0,5	6	5	7	6	6	5	7	6	6	5
experience or confidence in contractor or design builder	+	Points	0,7	8	8	8	9	8	8	8	9	8	8
pre-contract period (long, short)	+	Points	0,6	5	6	5	8	5	6	5	8	5	6
consultants (chosen by contractor or employer)	+	Points	0,2	3	5	6	8	3	5	6	8	3	5
sub-contractors (domestic, nominated)	-	Points	0,6	4	5	3	1	4	5	3	1	4	5
valuations of variations (expensive, cheap, at cost)	-	Points	0,7	5	7	8	5	5	7	8	5	5	7
completion	+	Points	0,6	6	8	7	9	6	8	7	9	6	8

Fig. 3.9. Fragment of the computer-aided development of the construction project management

Hence, Figure 3.11 gives explicit intermediate information about the influence of each criterion on the market value of the analyzed alternative. Traditional analysis methods do not facilitate such explicit analysis of factors affecting an alternative's market value. The MDSS-CPM system developed on the basis of multiple criteria analysis methods, which were created by the author of this research, allows to eliminate drawbacks of the traditional analysis and assessment methods, to take a new perspective on the assessment process, to improve objectiveness in determination of pluses and minuses for each alternative and also to validate the market value of alternatives.

desire of owner to control elements of project	+	Points	0,5	0,000514	0,000686	0,000772	0,000343	0,000514	0,000686	0,000772	0,000343	0,000514	0,000686
importance of cost to owner	+	Points	1	0,001157	0,001157	0,001157	0,001157	0,001157	0,001157	0,001157	0,001157	0,001157	0,001157
amount of risk owner wants to contract out	+	Points	0,6	0,00067	0,000766	0,000479	0,000862	0,00067	0,000766	0,000479	0,000862	0,00067	0,000766
availability of contractors	+	Points	0,8	0,000673	0,001178	0,001347	0,000505	0,000673	0,001178	0,001347	0,000505	0,000673	0,001178
local construction climate	+	Points	0,5	0,000579	0,000482	0,000675	0,000579	0,000579	0,000482	0,000675	0,000579	0,000579	0,000482
experience or confidence in contractor or design builder	+	Points	0,7	0,000786	0,000786	0,000786	0,000884	0,000786	0,000786	0,000786	0,000884	0,000786	0,000786
pre-contract period (long, short)	+	Points	0,6	0,000579	0,000694	0,000579	0,000926	0,000579	0,000694	0,000579	0,000926	0,000579	0,000694
consultants (chosen by contractor or employer)	+	Points	0,2	0,000126	0,00021	0,000253	0,000337	0,000126	0,00021	0,000253	0,000337	0,000126	0,00021
sub-contractors (domestic, nominated)	-	Points	0,6	0,000855	0,001068	0,000641	0,000214	0,000855	0,001068	0,000641	0,000214	0,000855	0,001068
valuations of variations (expensive, cheap, at cost)	-	Points	0,7	0,000648	0,000907	0,001037	0,000648	0,000648	0,000907	0,001037	0,000648	0,000648	0,000907
completion (fixed, controlled, at large)	+	Points	0,6	0,000556	0,000741	0,000648	0,000833	0,000556	0,000741	0,000648	0,000833	0,000556	0,000741
The sums of weighted normalized maximizing (projects 'pluses') indices of the alternative				0,0243	0,0253	0,0257	0,0246	0,0237	0,0247	0,0251	0,0248	0,0232	0,0244
The sums of weighted normalized minimizing (projects 'minuses') indices of the alternative				0,0074	0,0079	0,0075	0,0065	0,0069	0,0074	0,0072	0,0064	0,0069	0,0075
Significance of the alternative				0,0314	0,0322	0,0329	0,0326	0,0312	0,0317	0,0323	0,0327	0,0305	0,0312
Priority of the alternative				585	267	29	122	634	460	203	85	813	634
Utility degree of the alternative (%)				94,43%	96,84%	98,95%	98,04%	93,83%	95,34%	97,14%	98,34%	91,73%	93,83%

Fig. 3.10. Fragment of the multiple criteria analysis of the developed construction project management feasible alternatives

3.4. Manual Calculations

In order to demonstrate more properly the above case study (see Sub-Section 3.3) and check the consistency of the system by providing manual calculations [according to the method of multiple criteria complex proportional evaluation of the projects (COPRAS)] as follows.

The adapted method assumes direct and proportional dependence of significance and priority of the investigated versions on a system of criteria adequately describing the alternatives, and on the values and weight of the criteria. The system of criteria is determined and the values and the initial weight of the criteria are calculated by experts. All this information can be corrected by the interested parties taking into consideration their pursued goals and existing

capabilities. Hence, the assessment results of alternatives fully reflect the initial data jointly submitted by experts and interested parties. The determination of significance and priority of alternatives is carried out in four stages.

Stage 1. The weighted normalized decision making matrix D is formed. The purpose of this stage is to receive dimensionless weighted values from the comparative indexes. When the dimensionless values of the indexes are known, all criteria, originally having different dimensions, can be compared. The following formula is used for this purpose:

$$d_{ij} = \frac{x_{ij} q_i}{\sum_{j=1}^{n} x_{ij}}; \quad i = 1 \ldots m; \quad j = 1 \ldots n. \tag{3.1}$$

Here x_{ij} is the value of the i-th criterion in the j-th alternative of a solution; m is the number of criteria; n is the number of the alternatives compared; q_i is significance of i-th criterion.

ecommendations for user

Recommendations for user

Please select solution under consideration

Buildings

Qualitative and quantitative description of the alternatives

Quantitative and qualitative information pertinent to alternatives							
Criteria describing the alternatives	*	Measuring units	Weight	- Compared alternatives - Possible improvement of the analysed criterion in % - Possible increase of the market value of the alternative in % through increased value of the aforementioned criterion			
				House 1	House 2	House 3	House 4
Estimated costs	-	Eur	0,348	146000 (0%) (0%)	175000 (16,57%) (3,5364%)	162000 (9,88%) (2,1077%)	179000 (18,44%) (3,9343%)
Equivalent fuel needed for heating premises	-	T/Year	0,651	3,8 (21,05%) (8,4045%)	4,3 (30,23%) (12,0693%)	3 (0%) (0%)	4 (25%) (9,9804%)
Conveniences to use a heating system	+	Points	0,0209	0,5 (0%) (0%)	0,5 (0%) (0%)	0,5 (0%) (0%)	0,5 (0%) (0%)
Lasting of a building	+	Points	0,1965	1 (0%) (0%)	1 (0%) (0%)	1 (0%) (0%)	1 (0%) (0%)
Roof covering	+	Points	0,0073	0,9 (0%) (0%)	0,9 (0%) (0%)	0,9 (0%) (0%)	0,9 (0%) (0%)
General comfort	+	Points	0,0707	0,6 (66,67%) (2,8904%)	0,7 (42,86%) (1,8581%)	1 (0%) (0%)	0,6 (66,67%) (2,8904%)
General functional convenience	+	Points	0,0429	0,7 (42,86%) (1,1275%)	0,8 (25%) (0,6577%)	1 (0%) (0%)	0,7 (42,86%) (1,1275%)
Volumetric proportionality of premises	+	Points	0,0282	0,5 (100%) (1,7293%)	1 (0%) (0%)	1 (0%) (0%)	0,6 (66,67%) (1,1529%)
Living area	+	m2	0,0624	120 (67,5%) (2,5829%)	142 (41,55%) (1,5899%)	188 (6,91%) (0,2646%)	201 (0%) (0%)
Floor height	+	Points	0,0585	0,8 (12,5%) (0,4484%)	0,9 (0%) (0%)	0,9 (0%) (0%)	0,8 (12,5%) (0,4484%)
Class of a building according to its type	+	Points	0,0084	1 (0%) (0%)	1 (0%) (0%)	1 (0%) (0%)	1 (0%) (0%)
Garage influence	+	Points	0,0066	0,2 (0%) (0%)	0,2 (0%) (0%)	0,2 (0%) (0%)	0,2 (0%) (0%)

Internet

Fig. 3.11. Fragment of recommendations for managers regarding building

Following calculations are performed explaining the values presented in Table 3.1:

$$d_{11} = \frac{146000 \cdot 0.348}{146000 + 175000 + 162000 + 179000} = 0.0767;$$

$$d_{12} = \frac{175000 \cdot 0.348}{146000 + 175000 + 162000 + 179000} = 0.092;$$

$$d_{13} = \frac{162000 \cdot 0.348}{146000 + 175000 + 162000 + 179000} = 0.0852 \text{, and etc.}$$

The sum of dimensionless weighted index values d_{ij} of each criterion x_i is always equal to the significance q_i of this criterion:

$$q_i = \sum_{j=1}^{n} d_{ij}; \quad i = 1 \ldots m; \quad j = 1 \ldots n. \tag{3.2}$$

$$q_{11} = 0.0767 + 0.092 + 0.0852 + 0.0941 = 0.3480;$$

$$q_{12} = 0.1638 + 0.1854 + 0.1293 + 0.1725 = 0.6510;$$

$$q_{13} = 0.0052 + 0.0052 + 0.0052 + 0.0052 = 0.0209;$$

$$q_{14} = 0.0491 + 0.0491 + 0.0491 + 0.0491 = 0.1964 \text{, and etc.}$$

The value of significance q_i of the investigated criterion is proportionally distributed among all alternative versions a_j according to their values x_{ij}.

Stage 2. The sums of weighted normalized indexes describing the j-th version are calculated. The versions are described by minimizing indexes S_{-j} and maximizing indexes S_{+j}. The lower value of minimizing indexes is better (price of the technology and building, etc.). The greater value of maximizing indexes is better (comfortability of the construction works, etc.). The sums are calculated according to the formula:

$$S_{+i} = \sum_{i=1}^{m} d_{+ij}; \quad S_{-i} = \sum_{i=1}^{m} d_{-ij}; \quad i = 1 \ldots m; \quad j = 1 \ldots n. \tag{3.3}$$

$$S_{+1} = 0.0052 + 0.0491 + 0.0018 + 0.0146 + 0.0094 + 0.0045 + 0.0115 + 0.0138 +$$
$$0.0021 + 0.0016 + 0.006 + 0.0036 + 0.0115 + 0.0008 + 0.0024 + 0.0072 = 0.1451;$$

$$S_{-1} = 0.0767 + 0.1638 = 0.2405;$$

$$S_{+2} = 0.0052 + 0.0491 + 0.0018 + 0.0171 + 0.0107 + 0.0091 + 0.0136 + 0.0155 +$$
$$0.0021 + 0.0016 + 0.0076 + 0.0044 + 0.0115 + 0.0008 + 0.0012 + 0.0064 = 0.1577;$$

$$S_{-2} = 0.0920 + 0.1854 = 0.2774 \text{, and etc.}$$

The values S_{+j} [the greater is this value (project 'pluses'), the more satisfied are the interested parties] and S_{-j} [the lower is this value (project 'minuses'), the better is goal attainment by the interested parties] express the degree of goals attained by the interested parties in each alternative project. In any case the sums of 'pluses' S_{+j} and 'minuses' S_{-j} of all alternative projects are always respectively equal to all sums of significances of maximizing and minimizing criteria:

$$S_+ = \sum_{j=1}^{n} S_{+i}; \quad S_- = \sum_{j=1}^{n} S_{-i}; \quad i = 1 \ldots m; \quad j = 1 \ldots n. \tag{3.4}$$

$S_+ = 0.1451 + 0.1577 + 0.1748 + 0.1538 = 0.6314;$

$q_+ = 0.0209 + 0.1965 + 0.0073 + 0.0707 + 0.0429 + 0.0282 + 0.0624 + 0.0585 +$
$0.0085 + 0.0066 + 0.272 + 0.016 + 0.046 + 0.0031 + 0.0098 + 0.0272 = 0.6314;$

$S_- = 0.2405 + 0.2774 + 0.2145 + 0.2666 = 0.9990;$

$q_- = (-0.3480) + (-0.6510) = 0.9990$, and etc.

In this way, the calculations made may be additionally checked.

Stage 3. The significance (efficiency) of comparative versions is determined on the basis of describing positive projects ('pluses') and negative projects ('minuses') characteristics. Relative significance Q_j of each project a_j is found according to the formula:

$$Q_j = S_{+j} + \frac{S_{-\min} \sum_{j=1}^{n} S_{-j}}{S_{-j} \sum_{j=1}^{n} \left(S_{-\min} / S_{-j} \right)}; \quad j = 1 \ldots n. \tag{3.5}$$

$$Q_1 = 0.1451 + \frac{0.2145 \cdot 0.999}{0.2405 \cdot \left(\frac{0.2145}{0.2405} + \frac{0.2145}{0.2774} + \frac{0.2145}{0.2145} + \frac{0.2145}{0.2666} \right)} = 0.3924, \text{ and etc.}$$

Stage 4. Priority determination of projects. The greater is the Q_j the higher is the efficiency (priority) of the project.

The analysis of the method presented makes it possible to state that it may be easily applied to evaluating the projects and selecting most efficient of them, being fully aware of a physical meaning of the process. Moreover, it allowed formulating a reduced criterion Q_j which is directly proportional to the relative effect of the compared criteria values x_{ij} and significances q_i on the end result.

$$Q_3 > Q_1 > Q_2 > Q_4: \quad 0.4562 > 0.3924 > 0.3885 > 0.3855.$$

Complex systems are a scientific field which studies the common properties of systems that are considered fundamentally complex. It is also called

complex systems theory, complexity science, and study of complex systems, sciences of complexity, non-equilibrium physics, and historical physics. The key problems of complex systems are difficulties with their formal modeling and simulation. From such perspective, in different research contexts complex systems are defined on the base of their different attributes. Complex systems is a new approach to science that studies how relationships between parts give rise to the collective behaviors of a system and how the system interacts and forms relationships with its environment. In a business context, complexity management is the methodology to minimize value-destroying complexity and efficiently control value-adding complexity in a cross-functional approach (Wikipedia 2009c). Therefore, a method of determining the utility degree and market value of projects is appropriate for the analysis of complex systems.

Significance Q_j of project aj indicates satisfaction degree of demands and goals pursued by the interested parties - the greater is the Q_j the higher is the efficiency of the project. In this case, the significance Q_{max} of the most rational project will always be the highest. The significances of all remaining project are lower as compared with the most rational one. This means that total demands and goals of interested parties will be satisfied to a smaller extent than it would be in case of the best project.

Table 3.1. Construction project management multiple criteria analysis results

Quantitative information pertinent to projects										
Criteria describing the construction project management	*	Weight	Measuring units	Compared projects						
				a_1	a_2	...	a_j	...	a_n
X_1	z_1	q_1	m_1	d_{11}	d_{12}	...	d_{1j}	...	d_{1n}
X_2	z_2	q_2	m_2	d_{21}	d_{22}	...	d_{2j}	...	d_{2n}
X_3	z_3	q_3	m_3	d_{31}	d_{32}	...	d_{3j}	...	d_{3n}
...	...	...	...	...	...	...	...	...	...
X_i	z_i	q_i	m_i	d_{i1}	d_{i2}	...	d_{ij}	...	d_{in}
...	...	...	...	...	...	...	...	...	...
X_m	z_m	q_m	m_m	d_{m1}	d_{m2}	...	d_{mj}	...	d_{mn}
The sums of weighted normalized maximizing (projects 'pluses') indices of the project				S_{+1}	S_{+2}	...	S_{+j}	...	S_{+n}
The sums of weighted normalized minimizing (projects 'minuses') indices of the project				S_{-1}	S_{-2}	...	S_{-j}	...	S_{-n}
Significance of the project				Q_1	Q_2	...	Q_j	...	Q_n
Priority of the project				P_1	P_2	...	P_j	...	P_n
Utility degree of the project (%)				N_1	N_2	...	N_j	...	N_n

*Sign +/– indicates that a greater/lesser criterion value corresponds to its significance for a project manager.

The degree of project utility is directly associated with the quantitative and conceptual information related to it. According to this adapted method the degrees of utility of the project considered as well as the market value of a project being valuated are determined in seven stages. The formula used for the calculation of project aj utility degree N_j is given below (in percent):

$$N_j = \frac{Q_j}{Q_{\max}} \times 100\%; \quad j = 1 \ldots n. \tag{3.6}$$

$$N_1 = \frac{0.3924}{0.4562} \times 100\% = 86.01\%;$$

$$N_2 = \frac{0.3885}{0.4562} \times 100\% = 85.16\%;$$

$$N_3 = \frac{0.4562}{0.4562} \times 100\% = 100.00\%;$$

$$N_4 = \frac{0.3855}{0.4562} \times 100\% = 84.49\%;$$, and etc.

It must be noted that the results of manually performed calculations are adequate to the analysis results provided by the system. Thus the process of the analysis and assessment of construction project management and the related decision-making can be more objective, neutral and informative. The MDSS-CPM system can really help to assess the influence of various environment factors, to identify the critical values of factors, to make decisions on management, to plan the courses of action and to provide reliable information to investors and managers.

3.4. Concluding Remarks of Chapter 3

1. In a construction project management context, complexity management is the methodology to minimize value-destroying complexity and efficiently control value-adding complexity in a cross-functional approach. Therefore, a method of determining the utility degree and market value of projects is appropriate for the analysis of complex systems.
2. Since all complex systems have many interconnected components, the science of networks and network theory are important aspects of the study of complex systems. Therefore, a method of multiple criteria

multi-variant design of a project life is suitable for the analysis of complex systems.

3. A formalized presentation of the research shows how changes in the project, organizational and external environment affect the extent to which the goals pursued by various interested parties are satisfied, and cause respective changes in the value and utility degree of a construction project management. With this in mind, it is possible to solve the problem of optimization concerning the satisfaction of the clients, managers and other stakeholders' needs at reasonable expenditure rates. This demands that the analysis of the construction project management versions, allow for the determination of an optimal combination of goals to be pursued and the available finances.
4. The Construction Project Management Multiple Criteria Decision Support System was developed and based on the developed Model, complex systems theory and analysis of the existing information, knowledge, experts and decision support systems and in order to determine the most efficient versions of construction project management. The above System includes a database, a database management system, a model-base, a model-base management system and a manager interface.
5. Complex databases of construction project management and its stages were developed providing a comprehensive assessment of alternative versions from technical, technological, organizational, managerial, economic, qualitative, legal and other perspectives. Based on the above complex databases, the developed decision support systems enabling the user to analyze projects quantitatively (a system and subsystems of criteria, units of measure, values and significances) and conceptually (text, formula, schemes, graphs, diagrams, video tapes) were created.

General Conclusions

1. An analysis of global research shows that the existing intelligent systems do not perform the multi-variant design of construction project management alternatives
2. An original integrated project management model is developed on the basis of the complex systems theory and that of the multiple criteria analysis models. Model includes the six stages: (1) comparative description of the integrated project management; (2) comparison of integrated project management techniques; (3) multiple criteria analysis of integrated project management's components, selection of the most efficient version of project's management life, (4) development of general recommendations for improving the efficiency levels of construction man-agers and construction companies; (5) submission of particular recommendations for construction managers and construction companies; (6) transformational learning and redesigning the mental and practical behaviors.
3. The employed knowledge management models and theories into the integrated project management model ensure its versatility.

4. The integrated project management model has been verified in operational conditions and proved its adequacy, efficiency, id est. applicability for practical usage.
5. The performed investigations on the basis of developed model allowed to identify and to describe the major worldwide construction project management trends and subsequently to provide recommendations.
6. The suggested systems and subsystems of criteria relating to a construction project management, being based on economic, technical, technological, managerial, qualitative, legislative, social and other factors can be successfully serve as a basis for performing an analysis of the methods for management of construction projects.
7. Complex systems theory that has been applied to the construction project management model ensures its scientific validity.
8. A formalized presentation of the research shows how changes in the project, organizational and external environment affect the extent to which the goals pursued by various interested parties are satisfied, causes the respective changes in the value and utility degree of the construction project management. Taking into account the reasonable expenditure rates it is possible to solve the problem of optimization concerning the satisfaction of the clients, managers and other stakeholders. This demands that the analysis of the construction project management versions allows for the determination of an optimal combination of goals to be pursued compatible with the available finances.
9. The created Construction Project Management Multiple Criteria Decision Support System being developed on the basis of complex systems theory, that of developed Model and analysis of existing information, knowledge, experts opinions and analysis of decision support systems allow to determine the most efficient versions of construction project management. This System includes: database, database management system, model-base, model-base management system and manager interface.

References

Achterkamp, M. C.; Vos, J. F. J. 2007. Investigating the use of the stakeholder notion in project management literature, a meta-analysis. *International Journal of Project Management,* 26(7): 749–757.

Ahmad, I. 1990. "Decision-support system for modeling bid/no-bid decision problem". *Journal of construction engineering and management*, 1(16/4): 595–608.

Al Khattab, A.; Anchor, J.; Davies, E. 2007. Managerial perceptions of political risk in international projects. *International Journal of Project Management*, 25(7): 734–743.

Ancarani, A.; Capaldo, G. 2005. Supporting decision-making process in facilities management services procurement: A methodological approach, *Journal of Purchasing and Supply Management*, 11(5–6): 232–241.

Anton, D. W. 1988.Measurement of project success. *International Journal of Project Management*, 6(3): 164–9.

Avots, I. 1972. Projects in developing countries. *Business Horizons*, 15(4): 69–73.

Baiden, B. K.; Price, A. D. F.; Dainty, A. R. J. 2006. The extent of team integration within construction projects, *International Journal of Project Management*, 24(1): 13–23.

Baker, B.; Murphy, D.; Fisher D. 1983. *Factors affecting project success*. Project management handbook. New York: Van Nostrand Reinhold.

Baldwin, A. N.; Shen, L. Y.; Poon, C. S.; Austin, S. A., Wong, I. 2008. Modelling design information to evaluate pre-fabricated and pre-cast design solutions for re-

ducing construction waste in high rise residential buildings. *Automation in Construction*, 17(3): 333–341.

Ballestín, F.; Valls, V.; Quintanilla, S. 2009. Scheduling projects with limited number of preemptions *Computers & Operations Research*, 36(11): 2913–2925.

Bardwick, J. 1995. *Danger in the Comfort Zone*: How to Break the Entitlement Habit that's Killing American Business. American Management Association: New York. ISBN 0-8144-7886-7.

Bartholomew, D. 2008. Building on Knowledge: Developing Expertise, *Creativity and Intellectual Capital in the Construction Professions.* Wiley-Blackwell.

Bartlett, C.; Ghoshal, S.; Birkinshaw, J. 2004. *Transnational management: text, cases, and readings in cross-border management.* 4th ed. New York: McGraw-Hill.

Bejder, E. 1991 "From Client's Brief to End of Use: The Pursuit of Qua1ity", *Book-Conference, Practice Management*, Edited by Peter Barrett, University of Salford and Rodrick Males, University of Manchester, published by E & FN SPON, London, England. ISBN 0-419-17150-9.

Belassi, W.; Tukel, O. 1996. A new framework for determining critical success/failure factors in projects. *International Journal of Project Management*, 14(3): 141–151.

Blackman, D.; Henderson S. 2001. "Does a learning firm facilitate knowledge acquisition and transfer?", *Electronic Journal of Radical Organization Theory*.

Böck, S.; Kiermeier, C. 2003. Internet gestütztes Ausschreibungsmanagement. *Bauinformatik*, 3: 44–47, Berlin: Springer-VDI Verlag, p. 45.

Bradford, M. 2005. *Market for political risk cover broadens, softens*. Business Insurance; 39(24): 9.

Brink, C. 2004. *Measuring political risk: risks to foreign investment*. England, USA: Ashgate Publishing Limited.

Brown, A. W.; Adams, J. D.; Amjad, A. A. 2007. The relationship between human capital and time performance in project management: A path analysis, *International Journal of Project Management*, 25(1): 77–89.

Burmester, B. 2000. Political risk in international business. In: Tayeb M, editor. *International business: theories, policies, and practices.* London: Prentice Hall. 247–272.

Butler, K.; Joaquin, D. 1998. *A note on political risk and the required return on foreign direct investment*. J Int Business Stud; 29(3): 599–608.

Caldas, C. H.; Soibelman, L. 2003. Automating hierarchical document classification for construction management information systems, *Automation in Construction*, 12(4): 395–406.

Cameron, I. T. 2005. Modelling across the process life cycle: A risk management perspective, *Computer Aided Chemical Engineering*, 20(1): 3–19.

Chartered Institute of Management Accountants Management. 2001. *Accounting financial strategy. London:* BPP Publishing Limited.

Chen, T. Y.; Chen, Y. M. 2009. Advanced multi-phase trust evaluation model for collaboration between coworkers in dynamic virtual project teams *Expert Systems with Applications*, 36(8): 11172–11185.

Cheng, E. W. L.; Li, H.; Love, P. E. D.; Irani, Z. 2004. Strategic alliances: a model for establishing long-term commitment to inter-organizational relations in construction, Building and Environment, 39(4): 459–468.

Cheng, M.; Tsai, H.; Hsieh, W. 2009a. Web-based conceptual cost estimates for construction projects using Evolutionary Fuzzy Neural Inference Model. *Automation in Construction*, 18(2): 164–172.

Cheng, M. Y.; Tsai, H. C.; Lai, Y. -Y. 2009b. Construction management process reengineering performance measurements, *Automation in Construction*, 18(2): 183–193.

Cheng, M. Y.; Tsai, H. C.; Liu, C. L. 2009c. Artificial intelligence approaches to achieve strategic control over project cash flows *Automation in Construction*, 18(4): 386–393.

Ching-Lee, C.; Ou-Yang, C. 2009. A neural networks approach for forecasting the supplier's bid prices in supplier selection negotiation process. *Expert systems with Applications*, 36(2): 2961–2970.

Chou, J. 2009. Generalized linear model-based expert system for estimating the cost of transportation projects. *Expert Systems with Applications*, 36 (3/1): 4253–4267.

Chrisp, T. M.; Cairns, J.; Gulland, C. 2003. The development of roundwood timber pole structures for use on rural community technology projects, *Construction and Building Materials*, 17(4): 269–279.

Christodoulou, S. 2009. Construction imitating ants: Resource-unconstrained scheduling with artificial ants, *Automation in Construction*, 18(3): 285–293.

Constructability – A primer. 1986. Publication 3-1, Constructability Task Force, Construction Industry Institute, Austin, Tex.

Constructability concepts file. 1987. Publication 3-3, Construction lndustry Institute, Austin, Tex.

Constructability. 1990. The Construction Management Commitee of the ASCE Construction "Constructability and constructability programs: white research". *Journal of construction engineering and management*, 1(17/1).

Cooke-Davies, T. 2002. The "real" success factors on projects. *International Journal of Project Management*, 20(3): 185–90.

Dalkey, N.; Helmer, O. 1963. An experimental application of the delphi method to the use of experts. *Journal of Management Science*, 9: 458–467.

Daniell, M. 2000. *World of risk.* Singapore: John Wiley.

Darvish, M.; Yasaei, M.; Saeedi, A. 2009. Application of the graph theory and matrix methods to contractor ranking. *International Journal of Project Management*, 27(6): 610–619.

Diederichs, M. 2001. *Risikomanagement und Risikocontrolling* (Risk Management and Risk Controlling). Verlag Vahlen, p. 14.

East, E. W.; Martinez, J. C.; Kirby, J. G. 2009. Discrete-event simulation based performance quantification of web-based and traditional bidder inquiry processes. *Automation in Construction*, 18(2): 109–117.

El-Sawalhi, N.; Eaton, D.; Rustom, R. 2007. Contractor pre-qualification model: State-of-the-art. *International Journal of Project Management*, 25(5): 465–474.

Enge, F.; Huhnt, W .Optimal Component Types for the Design of Construction Processes. *Tsinghua Science & Technology*, 13(1): 317–324.

Eshtehardian, E.; Afshar, A.; Abbasnia, R. 2009. Fuzzy-based MOGA approach to stochastic time-cost trade-off problem. *Automation in Construction*, In Press, Corrected Proof, Available online.

Foran, B.; Lenzen, M.; Dey, Ch.; Marcela Bilek, M. 2005. Integrating sustainable chain management with triple bottom line accounting, *Ecological Economics*, 52(2): 143–157.

Freeman, M.; Beale, P. 1992. Measuring project success. *Project Management Journal*, 23(1): 8–17.

Göcke, B. 2002. *Risikomanagement für Angebots-und Auftragsrisiken von Bauprojekten* (Risk Management for Bid and Order Risks of Construction Projects). DVP Verlag, Wuppertal, p. 169.

Greek, D.; Pullin, J. 1999. Overrun, overspent, overlooked. Eng 12(3): 27–8. Bury St. Edmunds.

Guidelines for implementing a constructability program. 1987. Publication 3-2, Constmction Industry Institute, Austin, Tex.

Hayek, F. 1978. *The Results of Human Action but Not of Human Design*, in New Studies in Philosophy, Politics, Economics, Chicago: University of Chicago Press, 96–105.

Hayfield, F. 1979. Basic factors for a successful project. In: *Proceedings of the Sixth Internet Congress*, p. 7–37.

Hayles, N. K. 1991. *Chaos Bound*: *Orderly Disorder in Contemporary Literature and Science.* Cornell University Press, Ithaca, NY.

Hill, C. W. 2002. *International business: competing in the global marketplace*. 4th ed. London: MCGraw-Hill.

Howell, L. 2001. *The handbook of country and political risk analysis.* 3rd ed. USA: The Political Risk Services Group.

Ishikawa, K. 1984. Guide to Quality Control, Asian Productivity Organization, Tokyo.

Jepsen, A. L.; Eskerod, P. 2008. Stakeholder analysis in projects: Challenges in using current guidelines in the real world. *International Journal of Project Management.* 27(4): 335–343.

Juan, Y.; Perng, Y.; Castro-Lacouture, D.; Lu, K. 2009. Housing refurbishment contractors selection based on a hybrid fuzzy-QFD approach. *Automation in Construction*, 18(2): 139–144.

Kaklauskas, A.; Zavadskas, E. K.; Raslanas, S. 2005. Multivariant design and multiple criteria analysis of building refurbishments. *Energy and Buildings*, 37(4): 361–372.

Kerth, N. L. 2006. *Post Mortem, Projekte erfolgreich auswerten* (Evaluating Projects Successfully), p. 77.

Kettis, M. 2004. *The challenge of political risk: exploring the political risk management of Swedish multinational corporations*. Doctoral dissertation, Sweden: Stockholm University.

Kim, C.; Kim, H. S. H.; Han, Kim, C.; Kim, M. K.; Park, S. H. 2009a. Developing a technology roadmap for construction R&D through interdisciplinary research efforts. *Automation in Construction*, 18(3): 330–337.

Kim, D. Y.; Han, S. H.; Kim, H.; Park, H. 2009b. Structuring the prediction model of project performance for international construction projects: A comparative analysis, *Expert Systems with Applications,* 36(2): 1961–1971.

Kunz, J., Fischer, M. 2007. *Virtual Design and Construction*: Themes, Case Studies and Implementation Suggestions. p. 48.

Kurul, E. 2007 Social network analysis: a robust methodology to evaluate knowledge creation capability and absorptive capacity, Construction Management and Economics 25th Anniversary Conference, 16th–18th July 2007, University of Reading UK. Presented as part of one of the three keynote speech panels of the conference.

Lai, V. S.; Wong, B. K.; Cheung, W. Group decision making in multiple criteria environment: A case using the AHP in software selection. *European Journal of Operational Research*, 137(1): 134–144.

Lam, K. C.; Ng, S. T. 2006. A cooperative Internet-facilitated quality management environment for construction, Automation in Construction, 15(1): 1–11.

Lechner, Ch.; Müller-Stewens, G. 2003. Strategics Management, Schäffer-Poeschel Verlag, Stuttgart p. 205 et seq.

Lee, C. C.; Ou-Yang, C. 2009. A neural networks approach for forecasting the supplier's bid prices in supplier selection negotiation process. *Expert Systems with Applications*, 36(2/2): 2961–2970.

Lin, C.; Hsieh, P. J. 2004. A fuzzy decision support system for strategic portfolio management, *Decision Support Systems*, 38(3): 383–398.

Linde, F. 2005. *Ekonomie der Information, Göttinger Schriften zur Internetforschung*. Universitätsdrucke Göttingen, p. 33.

Liu, A.; Walker, A. 1998. Evaluation of project outcomes. *Construction Management & Economics*, 16(2): 209–219.

Long, L. D.; Ohsato, A. 2009. A genetic algorithm-based method for scheduling repetitive construction projects. *Automation in Construction*, 18(4): 499–511.

Love, P. E. D. 2009. Editorial: Communities and champions of practice: catalysts for learning and knowing. Construction Innovation: Information, Process, *Management,* 9(4): 365–371.

Martin, C. C. 1976. *Project management*. New York: Amaco.

Might, R. J.; Fisher, W. A. 1985. The role of structural factors in determining project management success. *IEEE Transactions on Engineenng Management*, 32(2): 121–4.

Miller, K. 1992. *A framework for integrated risk management in international business*. *International Business Stud*; 2: 311–31.

Mohan, S., 1990. Expert Systems Application in Construction Management and Engineering. *Journal of construction engineering and management* 116(1): 87–99.

Moran, T., editor. 2001. *International political risk management: exploring new frontiers*. Washington [DC]: World Bank Publications.

Morris, P.; Hough, G. 1987. *The anatomy of major projects*: A study of the reality of project management. New York: Wiley.

Mota, C. M. M.; Teixeira, A. A.; Alencar, L. H. 2009. A multiple criteria decision model for assigning priorities to activities in project management. *International Journal of Project Management*, 27(2): 175–181.

Nelson, H. 2006. Looking Back to Move Ahead: The Business Value of Retrospectives. In *Proceedings of the NCUR*, North Carolina, p. 2.

Ng, S. Th.; Skitmore, R. M.; Lam, K. C.; Poon, A. W. C. 2004. Demotivating factors influencing the productivity of civil engineering projects, *International Journal of Project Management*, 22(2): 139–146.

Olander, S.; Landin, A. 2005. Evaluation of stakeholder influence in the implementation of construction projects. *International Journal of Project Management,* 23(4): 321–328.

Palaneeswaran, E.; Ng, Th.; Kumaraswamy, M. 2006. Client satisfaction and quality management systems in contractor organizations, *Building and Environment*, 41(11): 1557–1570.

Pati, D.; Park, C.; Augenbroe, G. 2009. Roles of quantified expressions of building performance assessment in facility procurement and management. *Building and Environment*, 44(4): 773–784.

Pheng, L. S., Chuan, Q. T. 2006. Environmental factors and work performance of project managers in the construction industry. *International Journal of Project Management*, 24: 24–37.

Picot, A.; Reichwald, R.; Wiegand, R. 1997. *Information, Organization and Management*. John Wiley & Sons. p. 88.

Pinto, J. K.; Slevin, D. P. 1988. *Critical success factors in effective project implementation*. In: Cleland DI, King WR, editors. Project management handbook. New York: Van Nostrand Reinhold. p. 479–512.

Routledge. 2000. *Concise Routledge Encyclopedia of Philosophy*. Routlege. p. 951 .

Russell, A.; Staub-French, S.; Tran, N.; Wong, W. 2009. Visualizing high-rise building construction strategies using linear scheduling and 4D CAD. *Automation in Construction*, 18(2): 219–236.

Said, H.; Marzouk, M.; El-Said, M. 2009. Application of computer simulation to bridge deck construction: Case study. *Automation in Construction*, 18(4): 377–385.

Sayles, L. R.; Chandler, M. K. 1971. *Managing large systems*. New York: Harper and Row.

Sambasivan, M.; Wen Soon Y. 2006. Causes and effects of delays in Malaysian construction industry. *International Journal of Project Management*, 25(5): 517–26.

Scheer, A. -W.; Kruppke, H.; Heib, R. E-Government. 2003. *Processoptimierung in der öffentlichen Verwaltung*. Berlin: Springer Verlag, p. 32.

Schieg, M. 2008. Strategies for Avoiding Asymmetric Information in Construction Project Management. *Journal of Business Economics and Management,* 1: 47–51.

Schultzki-Haddouti, C. 2004. Bund kauft online. c't. *Magazin für Computer Technik*, 2: 29–32, Hannover: Heise Zeitschriften Verlag, p. 29.

Scott-Young, Ch.; Samson, D. 2008. Project success and project team management: Evidence from capital projects in the process industries, *Journal of Operations Management*, 26(6): 749–766.

Sidwell, A. C. 1983. *A critical study of project team, organizational forms within the building process.* Unpublished PhD thesis, University of Aston.

Skyttner, L. 1998. Information theory - a psychological study in old and new concepts. *Kybernetes*, 27(3): 284–311.

Stanley, W.; Faust, K. 1994. *Social Network Analysis*: Methods and Applications. Cambridge: Cambridge University Press.

Steiner, E. 2004. *Anreizkompatible Architektenentlohnung*, Vorschläge zur Reform der Honorarordnung für Architekten und Ingenieure. Gabler, p. 275.

Stosberg, J. 2005. *Political risk and the institutional environment for foreign direct investment in Latin America.* Frankfurt: Peter Lang.

Timmers, P. 2003. Lessons from B2B E-Business Models. *Zeitschrift für Betriebswirtschaft*, Ergänzungsheft 1/2003, Die Zukunft of the Electronic Business. Wiesbaden: Gabler Verlag, p. 2.

Turner, J. R.; Muller, R. 2005. The project manager's leadership style as a success factor on projects: a literature review. *Project Management Journal*, 36(1): 49–61.

Turner, J.; Mavin, S.; Minocha, S. 2006. "We will teach you the steps but you will never learn to dance", *The Learning Organization*; 13(4).

Twort, A. C.; Rees, J. G. 2004. The development of construction procedures, *Civil Engineering Project Management (Fourth Edition)*, 1–16.

Vincke, P. 1992. Multicriteria decision-aid, Wiley& Sons, Bruxelles.

Walsh, J. P.; Ungson, G. R. 1991. "Organizational Memory", *Academy of Management Review*. 16(1): 57–91.

Wang, H. F.; Hsu, F.-Ch. 2009. An integrated operation module for individual risk management *European Journal of Operational Research*, 198(2): 610–617.

Weber, B. J.; Chapman, G. B. 2005. The combined effects of risk and time on choice: Does uncertainty eliminate the immediate effect? Does delay eliminate the certainty effect? *Organizational Behaviour and Human Decision Process* 96: 104–118, p. 105.

Wenger, E.; Terberger, E. 1988. *Die Beziehung zwischen Agent und Prinzipal als Baustein einer Ökonomischen Theorie der Organisation*, Wirtschaftswissenschaftliches Studium 10: 506–514.

Wilkin, S. 2001. *Making political risk fit*. Risk Manage; 48(4): 80.

Yeo, R. K. 2006. Learning institution to learning organization: Kudos to reflective practitioners, *Journal of European Industrial Training*, 30(5).

Yih-Tong, S. P.; Scott, L. J. 2005. An investigation of barriers to knowledge transfer, *Journal of Knowledge Management*; 9(2).

Yu, W. ; Chang, P. ; Yao, S. H. ; Liu, S. 2009. KVAM: model for measuring knowledge management performance of engineering community of practice. *Construction Management and Economics*, 27(8): 733–747

Zhang, X.; Bakis, N.; Lukins, T. C.; Ibrahim, Y. M.; Wu, S.; Kagioglou, M.; Aouad, G.; Kaka, A. P.; Trucco, E. 2009. Automating progress measurement of construction projects. *Automation in Construction*, 18(3): 294–301.

Web links:

ACM Portal. *The Guide to Computing Literature*, 2009 // http://portal.acm.org/citation.cfm?id=1465222 (referred on 11/11/2009)

AIPMI. *PM Overview*, 2009 // http://www.aipmi.org/index.php?sec=mypmi (referred on 11/11/2009)

Anderson, D., McNeil, G. 2005. *Artificial Neutral Networks Technology*. // http://www.dacs.dtic.mil/techs/neutral.title.html (referred on 07/09/2009)

Australian Research Council. *Complex systems*, 2009 // http://www.arc.gov.au/general/glossary.htm (referred on 27/11/2009).

BOYD Construction. *Construction Management*, 2009 // http://www.boydcompanies.com/management.htm (referred on 11/11/2009)

Constructivism. *Glosary – General*, 2009 // http://www.nde.state.ne.us/read/framework/glossary/general_a-e.html (referred on 27/11/2009).

Cordoba. Construction Management – FAQ, 2009 // http://www.cordoba.ca/Construction_Management_Consulting/FAQ.html (referred on 11/11/2009)

eTrading Partners Limited. Glossary, 2009 // http://www.etpconsulting.co.uk/Business%20Continuity/business-continuity-glossary.htm (referred on 16/11/2009)

Glosary. *Constructivism*, 2009 // http://www.nrs.dest.gov.au/glossary.htm (referred on 22/11/2009).

HSI. Glossary of Terms, 2009 // http://www.haro-consulting.com/glossary/index.html (referred on 14/11/2009)

IEM. *About the IEM.*// http://www.biz.uiowa.edu/iem/about (referred on 07/09/2009).

Kota. Construction Management, 2009 // http://www.kotainc.com/services.html (referred on 11/11/2009)

Macmillan English Dictionary. *ELT terms*, 2009 // http://www.macmillandictionaries.com/glossaries/definitions/a-c/a_c.htm (referred on 25/11/2009).

MWH. Construction Management at Risk, 2009 // http://www.mwhglobal.com/MWHGlobal/CM_at_Risk.html (referred on 11/11/2009)

OpenLink. Virtual Design and Construction, 2009 // http://linkeddata.uriburner.com/about/html/http/dbpedia.org/resource/Virtual_Design_and_Construction (referred on 11/11/2009)

PediaView. Construction Management, 2009 // http://pediaview.com/openpedia/Construction_management (referred on 11/11/2009)

Quantum. Social network analysis, 2009 // http://www.quantum3.co.za/CI%20Glossary.htm (referred on 05/12/2009)

Reference.com. Construction Management, 2009 // http://www.reference.com/browse/wiki/Construction_management (referred on 11/11/2009)

Siegmann, J. M. Construction Consultant, 2009 // http://consulting.siegmann.org/construction-consultant/?pg=1 (referred on 11/11/2009)

Slideshare. Project Management Methodology, 2009 // http://www.slideshare.net/altaee/project-management-methodology-1735142 (referred on 11/11/2009)

Stuhlman, D. D. 2009. Stuhlman Management Consultants // http://home.earthlink.net/~ddstuhlman/index.html (referred on 14/11/2009)

Trinity College. *Cognitivism: Jean Piaget's Genetic Epistemology Theory*, 2009 // https://www.cs.tcd.ie/crite/lpr/teaching/cognitivism.html (referred on 14/11/2009).

Wason, T. D. Community of Practice, 2009 // http://www.twason.com/glossary.html (referred on 04/12/2009)

Wikipedia. *Cognitive science*, 2009a // http://en.wikipedia.org/wiki/Cognitive_Science (referred on 14/11/2009).

Wikipedia. *Complex adaptive systems*, 2009b // http://en.wikipedia.org/wiki/Complex_adaptive_system (referred on 14/11/2009).

Wikipedia. *Complex systems*, 2009c // http://en.wikipedia.org/wiki/Complex_systems (referred on 14/11/2009).

Wikipedia. *Network science*, 2009d // http://en.wikipedia.org/wiki/Network_science (referred on 14/11/2009).

Wikipedia. *Network theory*, 2009e // http://en.wikipedia.org/wiki/Network_theory#Social_network_analysis (referred on 14/11/2009)

Wikipedia. Project Manager, 2009f // http://en.wikipedia.org/wiki/Project_manager (referred on 11/11/2009)

List of Publications by the Author on the Topic of the Dissertation in the Reviewed Scientific Journals

Schieg, M. 2009. Model of Integrated Project Management. *Journal of business economics and management*, 10(2): 149–160. ISSN 1611-1699. (Thomson ISI Web of Science)

Schieg, M. 2008. Strategies for avoiding asymmetric information in construction project management // *Journal of business economics and management*. Vilnius: Technika, 9(1): 47–51. ISSN 1611-1699. (Thomson ISI Web of Science)

Schieg, M. 2007. Post-mortem analysis on the analysis and evaluation of risks in construction project management // *Journal of business economics and management*. Vilnius: Technika, 8(2): 145–153. ISSN 1611-1699. (EBSCO, ICONDA)

Schieg, M. 2006a. Elektroninių statybos darbų plėtra Vokietijoje // *Verslas: teorija ir praktika*. Vilnius: Technika, 2006, 7(3): 183–191. ISSN 1648-0627. (EBSCO, ICONDA)

Schieg, M. 2006b. Risk management in construction project management // *Journal of business economics and management*. Vilnius: Technika, 7(2): 77–83. ISSN 1611-1699. (EBSCO, ICONDA)

Schieg, M. 2005. Operation and development of electronic markets as prognostic instrument for business planning // *Journal of business economics and management*. Vilnius: Technika, 2005, 6(4): 225–230. ISSN 1611-1699. (EBSCO, ICONDA)

Martin Wolfgang Schieg

MULTIPLE CRITERIA ANALYSIS OF CONSTRUCTION PROJECT MANAGEMENT

Doctoral Dissertation

TECHNOLOGICAL SCIENCES,
CIVIL ENGINEERING (02T)

Martin Wolfgang Schieg

DAUGIAKRITERINĖ STATYBOS PROJEKTO VALDYMO ANALIZĖ

Daktaro disertacija

TECHNOLOGIJOS MOKSLAI,
STATYBOS INŽINERIJA (02T)

2010 07 19. 12,75 sp. l. Tiražas 20 egz.
Vilniaus Gedimino technikos universiteto
leidykla „Technika“,
Saulėtekio al. 11, 10223 Vilnius,
http://leidykla.vgtu.lt
Spausdino UAB „Baltijos kopija“
Kareivių g. 13B, 09109 Vilnius