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KNOWLEDGE MODEL FOR INTEGRATED CONSTRUCTION PROJECT MANAGEMENT

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Abstract. The aim of research was to develop a Knowledge model for integrated construction project management by undertaking a complex analysis of economic, legal / regulatory, technical, technological, organizational, managerial, social, cultural, political, ethical, psychological and educational factors affecting it, and to present recommendations on increasing competitive ability. A comprehensive research into the above research object required the application and integration of different knowledge management models and theories (community of practice, social network analysis, intellectual capital, information theory, complexity science, and constructivism).

Keywords: knowledge, model, integrated construction project management.

JEL Classification: D81.

INTEGRUOTO STATYBOS PROJEKTŲ VALDYMO ŽINIŲ MODELIS

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Santrauka. Straipsnio tikslas – pristatyti integruoto statybos projektų valdymo žinių modelį, atliekant kompleksinę jį veikiančių ekonominių, teisės / reguliavimo, techninių, technologinių, organizacinių, valdymo, socialinių, kultūrinių, politinių, etinių, psichologinių ir švietimo veiksnių analizę, pateikti rekomendacijų konkurencingumui didinti. Išsamus tyrimas pareikalavo skirtingų žinių valdymo modelių ir teorijų pritaikymo bei integravimo (bendrosios praktikos, socialinio tinklo analizės, intelektinio kapitalo, informacijos teorijos, kompleksinio mokslo, konstruktyvizmo).

Reikšminiai žodžiai: žinios, modelis, integruotas statybos projektų valdymas.

1. Introduction

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.

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 at least from several areas of expertise.

The purpose of the presented research is to develop a Knowledge model for integrated project management by undertaking a complex analysis of economic, legal / regulatory, technical, technological, organizational, managerial, social, cultural, political, ethical, psychological and educational factors affecting it, and to present recommendations on increasing competitive ability.

2. Integrated construction project management

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 (Queensland Government… 2010).
- 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 (The University of Zagreb 2010).
- 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 (Bridgefield Group 2010).
- 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 endeavours undertaken to achieve a desired outcome (Association… 2010).
- 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) (Brunswick 2010).
- A management philosophy that says efficient management will yield effective results. Specifically, efficient management of resources and constraints to perform tasks in order to achieve a desired result (Minnesota… 2010).
- Support of initiatives through the provision of project management (Advanced… 2010).
- PM 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 (Wrasmussen 2010)
- 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 (Construction… 2010).

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.

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.

A project manager is often a client representative and has to determine and implement the exact needs of the client, based on knowledge of the firm they are representing. The ability to adapt to the various internal procedures of the contracting party, and to form close links with the nominated representatives, is essential in ensuring that the key issues of cost, time, quality and above all, client satisfaction, can be realized.

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.

Construction project managers in the past were individuals, who worked in construction or supporting industries and were promoted to foreman. It was not until the late 20th century that construction and construction management became distinct fields.

Until recently, the industry lacked any level of standardization, with individual states determining the eligibility requirements within their jurisdiction. However, several Trade associations based in the United States have made strides in creating a commonly-accepted set of qualifications and tests to determine a project manager's competency:

– The Project Management Institute has made some headway into being a standardizing body with its creation of the Project Management Professional (PMP) designation.
– The Constructor Certification Commission of the American Institute of Constructors holds semiannual nationwide tests. Eight American Construction Management programs require that students take these exams before they may receive their Bachelor of Science in Construction Management degree, and 15 other Universities actively encourage their students to consider the exams.
– The Associated Colleges of Construction Education and the Associated Schools of Construction have made considerable progress in developing national standards for construction education programs.

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.

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.

Recently a different business model 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.

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:

– 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 *et al.* 2007).

There are two main advantages in 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.

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:

– 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 affect 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.

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 a construction management, it is worthwhile taking into account the suggestions of other researchers. This is explained by the fact that the aims 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 *et al.* (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 *et al.* (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. Shenhar *et al.* (1997) mentioned that it is necessary to understand the two components in order to measure project 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.

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 prequalification which depends on subjective judgements 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).

The most important element in construction procurement is the contractor selection, which can result from contractor's ranking. Contractor pre-qualification 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 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 2006).

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 optimised; 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 steps and dialogue steps.

Multiple criteria decision making methods have been applied to a variety of problems, such as real estate investment projects' evaluation (Ginevičius and Zubrecovas 2009; Ginevičius *et al*. 2009; Zavadskas *et al*. 2010), planning of construction (Kapliński 2008), construction decisions-making (Sarka *et al*. 2008), construction bidding (Seydel *et al*. 2001), project risk assessment (Zeng 2007), maintenance outsourcing (Almeida 2005), water supply management (Morais and Almeida 2007), renovation (Tupenaite *et al*. 2010), service outsourcing contracts (Almeida 2007), etc. Mian *et al*. (1999) show the main decision problems related to project management to be resource allocation, prioritising the project portfolio, selection of managers, budget evaluation and selection of sales persons.

Mota *et al*. (2008) 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.

Although the researchers from various countries engaged in the analysis of construction management life cycle and its stages they did not consider the research object being analyzed by the authors of this investigation. The latter may be described as follows: a life cycle of a construction management, the stakeholders involved in its design and realization as well as micro and macro environment having a particular impact on it making an integral whole. To investigate the research object defined in the present research, some methods of multiple criteria analysis were applied.

4. Determination of a set of criteria pertaining to the construction project management

One of the most effective ways to identify highly productive construction firms, procurers, etc. is to hold competitions for the contract. Now we will discuss this procedure from the client's point of view and 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 trust fullness 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) treat 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 paper is on the introduction of two types of indicators: (1) based on normative models in biophysics and physiology and (2) 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 (Guidelines… 1987).

Constructability can be described as:

– project management technique to review the construction processes from start to finish during pre-construction phrase;
– The ability to construct under conditions available (Haro-Consulting 2010).

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 is 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 on we shall briefly discuss three earlier mentioned criteria: contracting strategy, construction and risk management.

The process of making the contract, whatever the size, may be divided into three parts (the decision on the type of contract and the particular contract conditions and documentation under which the work will be carried out; the selection of the contractor; the establishment of the contract price or how the price will be arrived at) (Jamal *et al.* 1990).

The alternatives of contractors and types of contracts are estimated on the basis of the following criteria groups: the economic use of building resources; the assessment of the contractor's contribution in relation to the design; the incentives to make production cost savings and their control; continuity of work in all aspects; risk and assessment of who should take it, etc. (Jamal *et al.* 1990).

Once the completion date for a project has been established, owners should consider the various contracting possibilities:

1. Fixed price contract, with or without fluctuations, based on: Performance specification; Specification and drawings; Schedule of rates; Bills of quantities; Bills of approximate quantities.
2. Cost reimbursement contracts: Prime cost plus percentage; Prime cost plus fixed fee.
3. Target cost contracts.
4. Management contracts.
5. Design / build contracts.

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 to have 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… 1997).

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 programmes;
- ability to maintain programme;
- 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 employer rely extensively on sub-contractors?
- Were there any problems with payments to sub-contractors and suppliers?
- Were defects remedied promptly?
- Were final accounts settled satisfactorily?

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).

5. Modeling of construction project management

Construction projects are getting larger 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 interdisciplinary approach of combining different technology areas, is a new way of sparking off the currently stagnant level of construction technologies. A comprehensive technology roadmap was 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 were 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 were 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.* 2009).

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 takes place using 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, it examines 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.

Lee *et al.* (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. This quantitative method is a significant contribution to the field of quality performance measurement, because (1) SQFD is totally automated, (2) SQFD's reliability is higher than conventional QFD, and (3) SQFD efficiently deals with uncertainties in multi-attribute and multi-participant decision-making, and therefore generates more accurate results. The system helps to improve the D/B project bidding system.

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.

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.

Cheng *et al.* (2009) 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. Results show that the construction industry stands to benefit significantly in terms of a successful BPR design by adopting the proposed model.

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 brainstorming, and, implemented well they can provide clear, fast, and multi-dimensional feedback to the project team. Russell (2009) describes aspects of 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.

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 authors of this investigation. The latter may be described as follows: analysis of economic, legal / regulatory, technical, technological, organizational, managerial, social, cultural, political, ethical, psychological and educational factors by using different knowledge management models and theories (community of practice, social network analysis, intellectual capital, information theory, complexity science and constructivism).

6. Knowledge model for integrated project management

A traditional practice in project management is to analyze alternatives based on economic, legal / regulatory, technical, technological, organizational and managerial approaches. Social, cultural, ethical, psychological and educational aspects of project management are less used. In order to make an integrated analysis of a project management life cycle, such a cycle must be analyzed in an integrated manner using the system of criteria (Kanapeckiene *et al*. 2010).

The aim of the research was to produce a Knowledge model for integrated project management by undertaking a complex analysis of economic, legal / regulatory, technical, technological, organizational, managerial, social, cultural, political, ethical, psychological and educational factors affecting it and to present recommendations on increasing 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 economic, legal / regulatory, technical, technological, organizational, managerial, social, cultural, political, ethical, psychological and educational factors.

The level of efficiency of the integrated knowledge project management depends on the many economic, legal/ regulatory, technical, technological, organizational, managerial, social, cultural, political, ethical, psychological and educational factors and all these variable factors can be optimized. The main objective of this Model is to analyze the best experience 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 by using different knowledge management models and theories (community of practice, social network analysis, intellectual capital, information theory, complexity science and constructivism).

Above models and theories, as well as their application in construction, are briefly analysed.

The significance of knowledge management in the construction industry has been proved, as well as researched in academic literature (Li *et al*. 2002; Kazi 2005; Garcia 2005 and others). Indeed different authors present diverse approaches to knowledge management, as well as different knowledge management models, theories (community of practice, social network analysis, intellectual capital, information theory, complexity science, constructivism) and strategies the adjustment of which for the construction industry sometimes lacks an integrated approach.

Construction organisations 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 organisations); 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 analysed in next paragraphs.

Social network analysis is the mapping and measuring of links and relationships between organisations 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) analysed 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) analysed 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 uses the Internet to facilitate their activities. This facilitation may include forums, libraries, chat rooms, calendars and such as working papers, links, and a contacts directory, other goodies are shared here for all to use (Wason 2010). Yu *et al.* (2009) present 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 formalised 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 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 2010). 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.

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 behaviour 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… 2010). Many large construction projects are attributed to complex systems. Therefore, accumulation of experience and knowledge, as well as its multiple reuse 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" (Epistemology 2010). Cognitivism – one of the younger branches of epistemology – deals with consistent patterns of scientific cognition. The idea of cognitivism (Macmillan… 2010) is that learning is a conscious, rational process. People learn by making models, maps and frameworks in their mind.

In cognitivism (Jeant… 2010) 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. 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 2010). 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 organise experience, rather than discover reality (Glosary… 2010). Constructivism is a philosophy of learning used by the leading construction organisations to master the best construction practice.

Basing on the discussed theories, the Model developed by authors includes six stages.

Stage I. Comparative description of the integrated knowledge construction management (economic, legal/regulatory, technical, technological, organizational, managerial, social, cultural, political, ethical, psychological and educational factors) in developed countries and in Lithuania by using different knowledge management models and theories (community of practice, social network analysis, intellectual capital, information theory, complexity science, constructivism):

- A system of criteria characterizing the efficiency of integrated knowledge construction 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 knowledge construction management of developed countries and Lithuania is given in conceptual (textual, graphical, numerical, etc.) and quantitative forms.

Stage II. A comparison and contrast of integrated knowledge construction management in developed countries and Lithuania by using different knowledge management models and theories:

- Identifying the global development trends (general regularities) of the integrated knowledge construction management;
- Identifying integrated knowledge construction management differences between developed countries and Lithuania;
- Determining pluses and minuses of these differences for Lithuania;
- Determining the best practice for integrated knowledge construction 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 development of some of the general recommendations as how to improve the knowledge levels for construction managers and construction firms.

Stage IV. Submission of particular recommendations to construction managers and construction firms. Each of the general recommendations proposed in the fifth stage carries several particular alternatives.

Stage V. Multiple criteria analysis of integrated knowledge construction management's components and selection of the most efficient version of project's management life cycle. After this stage, the received compatible and rational components of an integrated construction knowledge management are joined into the full integrated construction knowledge management process.

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

- 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 by managers' initial behaviour are; redesigning managers' core patterns of thought and behaviour);
- Performance of transformational learning (acquiring new manners of technological, social, ethical, etc. behaviour, getting better understanding of how to interact with micro and macro environment) and redesigning the behaviour.

7. Conclusions

Construction companies should be well informed of the economic, legal / regulatory, technical, technological, organizational, managerial, social, cultural, political, ethical, psychological and educational levels in which the companies operate. The above environment can create or eliminate opportunities and threats. Construction companies analyze the above factors and distribute the company resources to take advantage of opportunities and to minimize threats to the company's activities. Economic, legal/regulatory, technical, technological, organizational, managerial, social, cultural, political, ethical, psychological and educational factors can be optimized. These questions have been analysed in this paper.

References

Ahmad, I. 1990. Decision-support system for modeling bid/no–bid decision problem, *Journal of Construction Engineering and Management* 116(4): 595–608. doi:10.1061/(ASCE)0733-9364(1990)116:4(595)

Almeida, A. T. 2005. Multicriteria modelling of repair contract based on utility and ELECTRE I method with dependability and service quality criteria, *Annals of Operations Research* (138): 113–126. doi:10.1007/s10479-005-2448-z

Almeida, A. T. 2007. Multicriteria decision model for outsourcing contracts selection based on utility function and ELECTRE method, *Computers and Operations Research* 34(12): 3569–3574. doi:10.1016/j.cor.2006.01.003

Association for project management. 2010 [online], [cited 2 December 2010]. Available from Internet: <http://www.apm.org.uk/Definitions.asp>.

Australian Research Council. Complex systems. 2010 [online], [cited 2 December 2010]. Available from Internet: <http://www.arc.gov.au/general/glossary.htm.

Bartholomew, D. 2008. *Building on Knowledge: Developing Expertise, Creativity and Intellectual Capital in the Construction Professions*. Wiley-Blackwell. 320 p.

Bridgefield Group. 2010 [online], [cited 2 December 2010]. Available from Internet: <http://www.bridgefieldgroup.com/bridgefieldgroup/glos7.htm>.

Cheng, M.; Tsai, H.; Liu, C. 2009. Artificial intelligence approaches to achieve strategic control over project cash flows, *Automation in Construction* 18(4): 386–393. doi:10.1016/j.autcon.2008.10.005

Chou J.-S. 2009. Generalized linear model-based expert system for estimating the cost of transportation projects, *Expert Systems with Applications: An International Journal* 36(3): 4253–4267. doi:10.1016/j.eswa.2008.03.017

Constructability Concepts File. 1987. Austin: Construction Industry Institute.

Constructability. The Construction Management Committee of the ASCE Construction Division. 1990. Constructability and Constructability Programs: White Paper, *Journal of Construction Engineering and Management* 117(1): 67–89.

Construction Management Association of America. 2010 [online], [cited 2 December 2010]. Available from Internet: <http://cmaanet.org/cmci/application_definitions.php>.

Constructivism. Glosary – General. 2010 [cited 2 December 2010]. Available from Internet: <http://www.nde.state.ne.us/read/framework/glossary/general_a-e.html>.

Darvish, M.; Yasaei, M.; Saeedi, A. 2009. Application of the graph theory graph theory and matrix methods to contractor ranking, *International Journal of Project Management* 27(6): 610–619. doi:10.1016/j.ijproman.2008.10.004

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. doi:10.1016/j.autcon.2008.05.003

El-Sawalhi N.; Eaton D.; Rustom, R. 2007. Contractor's prequalification model: State-of-the-art, *International Journal of Project Management* 25(5): 465–474. doi:10.1016/j.ijproman.2006.11.011

Epistemology. 2010 [cited 2 December 2010]. Available from Internet: <http://www.parliament.vic.gov.au/SARC/E-Democracy/Final_Report/Glossary.htm>.

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

Garcia, M. A. 2005. Challenges of the construction sector in the global economy ant the knowledge society, *International Journal of Strategic Property Management* 9(2): 65–77.

Ginevičius, R.; Zubrecovas, V. 2009. Selection of the optimal real estate investment project basing on multiple criteria evaluation using stochastic dimensions, *Journal of Business Economics and Management* 10(3): 261–270. doi:10.3846/1611-1699.2009.10.261-270

Ginevičius, R.; Zubrecovas, V.; Ginevičius, T. 2009. Nekilnojamojo turto investicinių projektų efektyvumo vertinimo metodikos [Methodology of real estate investment projects' evaluation], *Verslas: teorija ir praktika* [*Business: Theory and Practice*] 10(3): 181–190. doi:10.3846/1648-0627.2009.10.181-190

Glosary. Constructivism. 2009 [cited 2 December 2010]. Available from Internet: <http://www.nrs.dest.gov.au/glossary.htm>.

Guidelines for Implementing a Constructability Program. 1987. Austin: Construction Industry Institute.

Haro-Consulting. 2010 [cited 2 December 2010]. Available from Internet: <http://www.haro-consulting.com/glossary/index.html>.

Jamal, F.; Al-Bahar; Crandall K. C. 1990. Systematic risk management approach for construction projects, *Journal of Construction Engineering and Management* 116(3): 533–547. doi:10.1061/(ASCE)0733-9364(1990)116:3(533)

Jean Piaget's Genetic Epistemology Theory. 2010 [cited 2 December 2010]. Available from Internet: <https://www.cs.tcd.ie/crite/lpr/teaching/cognitivism.html>

Kanapeckiene, L.; Kaklauskas, A.; Zavadskas, E. K.; Seniut, M. 2010. Integrated knowledge management model and system for construction projects, *Engineering Applications of Artificial Intelligence* 23(7): 1200–1215. doi:10.1016/j.engappai.2010.01.030

Kapliński, O. 2008. Planning instruments in construction management, *Technological and Economic Development of Economy* 14(4): 449–451. doi:10.3846/1392-8619.2008.14.449-451

Kazi, A. S. 2005. *Knowledge Management in the Construction Industry: A Socio-Technical Perspective*. London: Idea Group Publishing. 384 p.

Kim, C.; Kim, H.; Han, S. H.; Kim, C.; Kim, M. K.; Park, S. H. 2009. Developing a technology roadmap for construction R&D through interdisciplinary research efforts, *Automation in Construction* 18(3): 330–337. doi:10.1016/j.autcon.2008.09.008

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

Kurul, E. 2007. Social network analysis: a robust methodology to evaluate knowledge creation capability and absorptive capacity, in *Construction Management and Economics 25th Anniversary Conference*, Reading, UK, 2007. Reading: University of Reading.

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): 2961–2970. doi:10.1016/j.eswa.2008.01.063

Li, H.; Tang, S.; Man, K. F.; Love, P. E. D. 2002. VHBuild.com: a Web-based system for managing knowledge in projects, *Internet Research: Electronic Networking Applications and Policy* 12(5): 371–379. doi:10.1108/10662240210447128

Love, P. D. 2009. Communities and champions of practice: catalysts for learning and knowing, *Construction Innovation* 9(4): 365–377. doi:10.1108/14714170910995912

Macmillan English Dictionary. 2010 [online], [Cited 2 December 2010]. Available from Internet: <http://www.macmillandictionaries.com/glossaries/definitions/a-c/a_c.htm>.

Mian, S. A.; Dai, C. X. 1999. Decision-making over the project life cycle: an analytical hierarchy approach, *Project Management Journal* (30): 40–52.

Minnesota State University Mankato. 2010. [cited 2 December 2010]. Available from Internet: <http://krypton.mnsu.edu/~tony/courses/609/PERT/defs.html>.

Mohan, S. 1990. Expert systems applications in construction management and engineering, *Journal of Construction Engineering and Management* 116(l): 87–99. doi:10.1061/(ASCE)0733-9364(1990)116:1(87)

Morais, D. C.; Almeida, A. T. 2007. Group decision-making for leakage management strategy of water distribution network, *Resources, Conservation and Recycling* 52(2): 441–459. doi:10.1016/j.resconrec.2007.06.008

Mota, C. M. M.; Almeida, A. T.; Alencar, L. H. 2008. A multiple criteria decision model for assigning priorities to activities in project management, *International Journal of Project Management* 27(2): 175–181. doi:10.1016/j.ijproman.2008.08.005

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. doi:10.1016/j.buildenv.2008.06.018

Pinto, J. K.; Slevin, D. P. 1988. Project Success: Definitions and Measurement Techniques, *Project Management Journal* 19(1): 67–72.

Quantum. 2010. *Social network analysis* [cited 2 December 2010]. Available from Internet: <http://www.quantum3.co.za/CI%20Glossary.htm>.

Queensland Government Chief Information Center. 2010 [cited 2 December 2010]. Available from Internet: <http://www.qgcio.qld.gov.au/qgcio/resources/glossary/Pages/glossaryp.aspx>.

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

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. doi:10.1016/j.autcon.2008.08.001

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. doi:10.1016/j.autcon.2008.11.004

Sarka, V.; Zavadskas, E. K.; Ustinovicius, L.; Sarkiene, E.; Ignatavicius, C. 2008. System of project multicriteria decision synthesis in construction, *Technological and Economic Development of Economy* 14(4): 546–565. doi:10.3846/1392-8619.2008.14.546-565

Schieg, M. 2006. Risk management in construction project management, *Journal of Business Economics and Management* 7(2): 77–83.

Schieg, M. 2007. Post-mortem analysis on the analysis and evaluation of risks in construction project management, *Journal of Business Economics and Management* 8(2): 145–153.

Seydel, J.; Olson, D. I. 2001. Multicriteria support for construction bidding, *Mathematical and Computer Modelling* 34(5): 677–701. doi:10.1016/S0895-7177(01)00091-7

Shenhar, A. J.; Levy, O.; Dvir, D. 1997. Mapping the dimensions of project success, *Project Management Journal* 28(2): 5–13.

Sidwell, A. C. 1984. The time performance of construction projects, *Architectural Science Review* (27): 85–91.

Skyttner, L. 1998. Information theory – a psychological study in old and new concepts, *Kybernetes* 27(3): 284–311. doi:10.1108/03684929810209496

Stuhlman Management Consultants. 2010. *Intellectual Capital* [online], [cited 2 December 2010]. Available from Internet: <http://home.earthlink.net/~ddstuhlman/defin1.htm>.

The University of Zagreb. 2010 [online], [cited 2 December 2010]. Available from Internet: <http://www.unizg.hr/tempusprojects/glossary.htm>.

Tupenaite, L.; Zavadskas, E. K.; Kaklauskas, A.; Turskis, Z.; Seniut, M. 2010. Multiple criteria assessment of alternatives for built and human environment renovation, *Journal of Civil Engineering and Management* 16(2): 257–266. doi:10.3846/jcem.2010.30

Vincke, P. 1992. *Multicriteria decision-aid*. Chichester: John Wiley. 154 p.

Wason, T. D. 2010. *Community of Practice* [cited 2 December 2010]. Available from Internet: <http://www.twason.com/glossary.html>.

Wrasmussen. 2010 [cited 2 December 2010]. Available from Internet: <http://www.wrasmussen.gov.ck/index.php>.

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. doi:10.1080/01446190903074978

Zavadskas, E. K.; Kaklauskas, A.; Banaitis, A. 2010. Real estate's knowledge and device-based decision support system, *International Journal of Strategic Property Management* 14(3): 271–282. doi:10.3846/ijspm.2010.20

Zeng, J.; An, M.; Smith, N. J. 2007. Application of a fuzzy-based decision making methodology for construction project risk assessment, *International Journal of Project Management* 25(6): 589–600. doi:10.1016/j.ijproman.2007.02.006

Zhang, X.; Bakis, N.; Lukins, T. C. *et al*. 2009. Automating progress measurement of construction projects, *Automation in Construction* 18(3): 294–301. doi:10.1016/j.autcon.2008.09.004

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