CIB World Building Congress 2019
Hong Kong SAR, China
17 – 21 June 2019

Reshaping approaches to manage construction projects for the needs of smart built environments

Kalle Kähkönen,
Tampere University
(email: kalle.e.kahkonen@tuni.fi)
Marko Keinänen,
Tampere University
(email: marko.keinanen@tuni.fi)
Marco Bragadin,
University of Bologna
(email: marcoalvise.bragadin@unibo.it)

Abstract

The relevance of systems thinking as a competence of significance for project managers has been pointed out particularly in publications by project management associations such as IPMA and APM. Particularly it is complex projects where systems thinking can have an important role. Those disclose the need for holistic systems approaches where viable project systems can be designed. As a project planning solution, the resultant project system represents an overall structure to be used when the project logic is communicated and various project stakeholders are engaged. The project system can capture the principles of significance and associated processes for explaining the key elements of targeted project performance. As a project management solution, the project system can help to understand the behavior of project in question. The explained systems approach has gained rather limited presence in research addressing construction project management. This paper shall present main results of a research effort, which included development of a solution, termed as integrative project system, for designing actual project systems for collaborative construction projects, which are seen as important vehicles for reaching smart built environments. Here collaborative construction projects are understood as endeavors where key partners are closely operating together with shared risks and opportunities for reaching highest possible performance and benefit. For this type of construction projects, the actual practices and processes are rather poorly understood, often leading to disappointments. The resultant solution explains the structure of project system for collaborative construction projects (principles, key elements and their structuring). It can be used as starting point for designing needed project systems. The gained results are based on an action research that was carried out in co-operation with representatives from public and private sectors.

Keywords: construction projects, planning, management, integration, collaboration

1. Introduction

For the implementation of building projects, there are traditional implementation models and newer solutions such as the alliance delivery model where the focus is on co-operation between different parties. Designing an implementation model for a particular project is initially a selection exercise where knowledge and experiences of in-house experts or guidance by external consultants play important role (Masterman & Duff, 1994). Consciously or unconsciously, this also includes holistic thinking and review of the construction project as a system.

It is obvious that that the management and successful delivery of construction projects for smart building environments are increasingly challenging and are thus requiring new solutions and research towards those. Smart buildings and built environment encompass new functions and the resultant products needs to meet new expectations of professionals from different disciplines, and, the expectations of citizens (BPIE, 2017). The total project environment is increasingly complex with high number if various interdependencies between different project stakeholders. This paper and research behind have its focus on project system as a potential solution for framing, understanding and having a shared understanding of this kind of complex project environment.

2. Related Work

2.1 Systems thinking

The traditional starting points of systems thinking are in system analysis (system engineering). System analysis aims to model and understand the operation of complex entities and systems that have otherwise been impossible or extremely difficult to approach using traditional mathematical models. The resulting systems thinking can be described as a discipline for seeing wholes rather than parts (Senge, 1990). In principle, applications often involve uncertainty, human activity and behavior, subjective assessment and anticipation of decision-making situations. The result can be, for example, a simulation model for strategic decision-making. For decades, systems thinking has been applied to very diverse objects and needs, but the challenges described above have typically been the starting point for utilizing system analysis. Examples of applications include: new forms of energy and their use, energy-efficient buildings and society for sustainable development, waste management and circular economy, business intelligence. The term system theory is also often used alongside systems thinking.

The potential of systems thinking is enormous because, in addition to technical systems, almost all human activities can be viewed and analyzed as a system. The basis for describing systems thinking and dynamic interactions within systems and modeling them can be traced back to the 1960s (von Bertalanffy, 1968). Broadly speaking, system thinking can be thought to form an integral part of a large part of all scientific research. Many demanding problems have been solved by system thinking. At the same time, methods for system analysis and modeling for specific needs, such as gray systems, have been progressively developed, which refers to items for which only incomplete information is available or where the operation of objects is subject to uncertainty (Liu et al, 2015). The theory of gray systems and its applications have significantly expanded the applications of system thinking.

Different levels of abstraction can be identified in system thinking and system analysis. At the most theoretical level, system analysis and modeling are pure mathematics. At higher abstract levels, system thinking can mean the system's diagrams that can be used to conceive, structure, and learn how systems work and how to plan how they should work.

2.2 Project as a system

The tasks and involvement of the various operators involved in a construction project can vary between different project phases. Here, the system model can contribute to clarifying roles and expressing expectations about these roles. To understand how the construction process works as a system, one must understand the diversity of closed, open and complex systems. In a closed system, events outside the system do not affect the system itself and are therefore highly predictable. Machines

can be thought of as closed systems whose parts are selected to perform a particular function under certain conditions and to produce a predefined work result. If there is a change in the circumstances in which the machine is designed, the machine will not adapt. An open system adapts to changes in its operating environment. Thus, the operating system of an open system affects the system, but the open system itself also affects its operating environment. The open system is dynamic and adapts to its environment by adapting its structure and processes. The open system becomes complex when it has continuous two-way interactions, i.e. feedback (Forrester, 1994). A project can be classified as a complex system (Figure 1).

System thinking has aroused interest in project management and in the world of projects (Emes & Griffiths, 2018). It is seen as a way of approaching certain tasks analytically and as a further opportunity to better understand the world of complex projects and situations. Modern project management aims to comprehensively manage and understand the world of projects and hence these overall solutions have been described as systemic (Kerzner, 2009). System thinking and its management have been further identified as areas of competence in project management that can achieve better performance levels (APM, 2012; IPMA, 2015).

In construction projects the customer's wishes, needs and requirements must be taken into account and the processes adjusted to achieve the goals. It is already possible to have more than 100 service providers in a normal residential building project (Sorri & al, 2013). In addition, there are a number of stakeholders directly or indirectly involved in building projects (e.g. building control, other authorities, employee and employer associations, NGOs, as well as individual citizens). All parties involved may have feedback on the project. Based on Salminen's (2005) research results, 40% of the success of the construction project is explained by factors outside the project. Walker (2013) concludes that project management should focus on:

- Identify, communicate, and adapt system objectives
- Ensure that all parts of the system work effectively
- Ensure that appropriate connections are made between different parts
- Maintain active connections to work effectively
- Combine the entire system with its operating environment and adaptive system changes to its operating environment

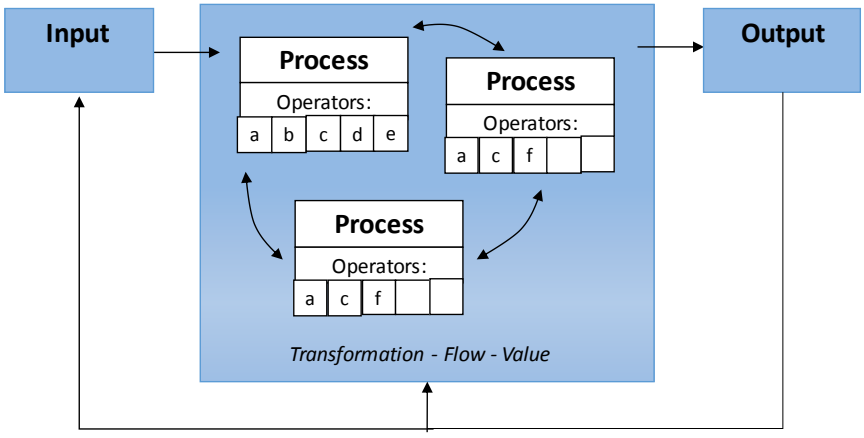

Figure 1: Project as a system of operators and their interplay

2.3 Collaborative construction projects

Improved level of co-operation towards collaboration between different parties involved in construction operations has been a long-term target for the real estate and construction sector. In partnership arrangements such as joint-ventures the main was first on company level commercial and contractual arrangements. Soon it was recognized that deeper and operation co-operation requires new process solutions e.g. for sharing risks and incentives. Since then the construction project systems that promote cooperation have been the subject of continuous development. Worldwide, this target has been approached in several ways. Project partnering (PP) delivery model aiming to improve cooperation within existing frameworks has its roots in the United States in large military projects in the 1980s, and more recently it has seen as a response to the high levels of conflict typically present in the construction industry (Eriksson, 2008). After originating in UK, Project Alliance (PA) delivery model became successful in Australian oil, gas and mining projects (Ross, 2009). The integrated project delivery (IPD) model from the United States has close links to the Lean Construction's principles practices (AIA, 2007, Jørgensen and Emmitt, 2007). Now we can see a range of solutions that can provide basis for multi-trade team work from design to construction operations and information sharing. Those solutions can bind different project players together in a manner where clear benefits can be reached compared with traditional project operations.

Inside PP, PA, IPD and other relational delivery models we can recognize a common target which is collaboration between different project stakeholders. Collaborative construction projects and their practices represent the general objective where the named deliver models are its practical instances. Since 2011, more than 50 “alliance construction projects” have been started in Finland. The total value of those is over € 3 billion. In these projects the main target is to reach the collaboration stage and, finally, its benefits. With these industrial maneuvers and among professionals involved the term alliance is used to mean project set-ups that include principles from lean construction, have a sort of risk and incentives sharing conditions as in project alliances and are putting emphasis on information management.

Construction projects with special delivery arrangements for enabling high level of cooperation and collaboration between project partners are gaining growing popularity. At the same time those are also objects for research based evidence and conclusions over the project models in questions, human aspects and cultural challenges just to mention here some current topics of interest among scholars (Tadayon, 2018; Asmar et al, 2013; Franz et al, 2017). Apparently, our knowledge base over the collaborative construction projects is now growing strongly.

3. Methodology

This article is based on the results of the RAIN research and development project. The RAIN project was a joint project of thirteen companies from the real estate and construction sector to develop building integration capacity (2016-2018). The RAIN project included five work packages:

WP1 Project System Design
WP2 Integration Mechanisms
WP3 Flow
WP4 Information Management
WP5 Integration Capacity

The WP1 Project System Design targeted to create the conditions and framework for an integrated approach and implementation according to common goals. According to the basic viewpoint, each project system for integrated construction should be individually designed and at the same time the project implementation planning should be carried out as comprehensively as possible. The aim of the work package has been to describe the elements and processes involved in designing an integrative project system that can be used as a basis for designing a project system. The work package as a whole has been modeling using system thinking.

The starting point for this is literature research which particularly focused on experienced from IPD projects. In connection with the Rain project, five dedicated workshops were held. Using hermeneutic analysis, industry representatives, together with researchers, have developed project design solutions for the project system. Understanding is produced through systematic interpretation processes. These processes are known as a hermeneutic circle Interpretation of details affects the interpretation of the entire phenomenon. During the implementation of the Rain project, these sub-solutions have been further presented to business representatives. The results have been improved and further developed based on the feedback received. In addition, interviews were done on experiences and lessons learned on ongoing collaborative construction projects.

4. Integrative project system

4.1 The overall solution

A typical characteristic of construction is the separation between design and construction, which is a significant source of problems and project inefficiencies (Jørgensen and Emmitt, 2007). The integrative project system is a collaborative approach that aims for planning and determining predictable performance for construction projects. The integrative project system is defined by a set of principles and collaborative mechanisms integrated in a complex system. In accordance with the principles of system thinking, complex systems can be divided into subsystems, or partial systems. and their management. Partial systems may be the systems of the subscriber or service providers, or other sub-systems defined / developed for the project, i.e. a set of processes and specific tasks (Figure 2). This concept is one of the starting points for the proposed overall solution.

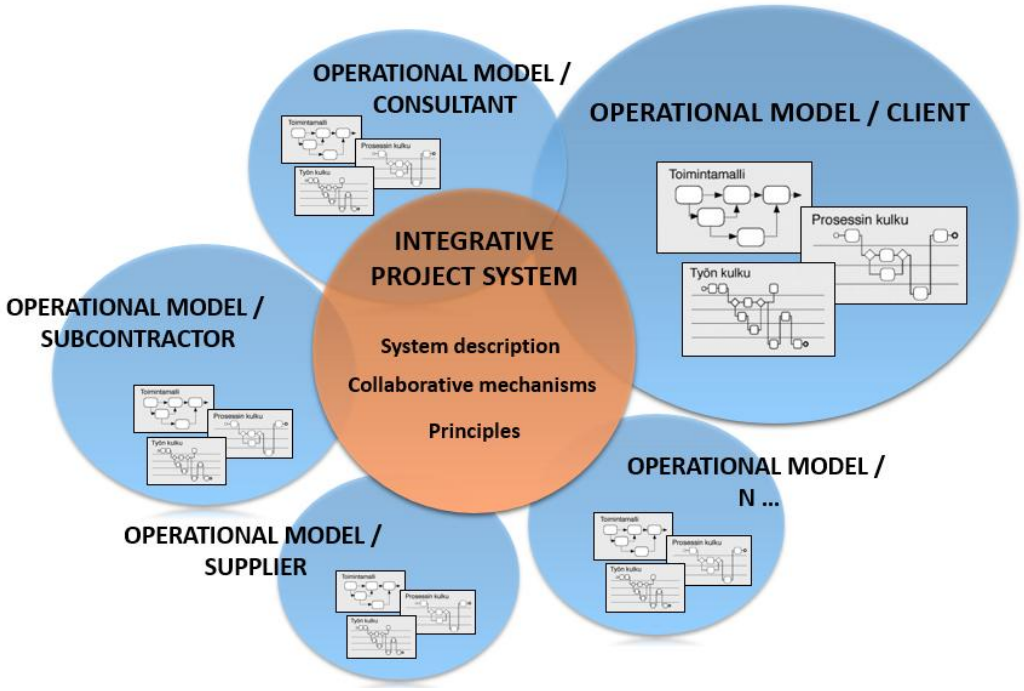

Figure 2: Through an integrative project system, the different actors' own operating models and solutions can be combined into a cooperative entity.

Attention should be paid to the assessment and identification of unstable components. Identified unstable subsystems are being developed for stability.

Additional key principles are:

- Understanding the project as a whole rather than parts
- Explain the basic structure of the project and its main parts
- Integration of sub-systems using interface thinking.
- The project system can be formed in stages
- The basis for thinking and doing in the same direction, i.e. the integration of different players
- As a result, to present an overall solution for the project implementation (principles, procedures, processes and their interaction)

4.2 The main elements

The main components of an integrative project system are the project definition system and the project delivery system. The names refer to their use during the project life-cycle, i.e. the project definition system is a construction client-driven entity where main object is the early development and definition phases of the construction project. The project delivery system further focuses on the design and implementation phases of the project (Figure 3).

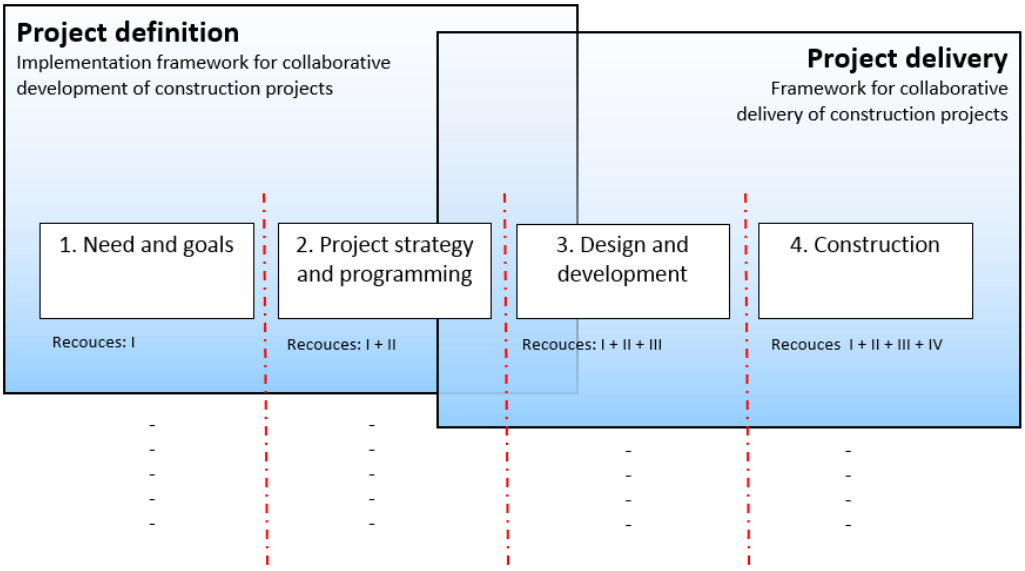

Figure 3: Integrative project system for collaborative construction

The project system is a subscriber-driven total solution for project implementation for integrated construction projects. It defines the key starting points and principles for a project under development
- Objectives of the project
- Necessary skills (required skills)
- Collaboration and information sharing
- Create the necessary conditions and opportunities for planning and implementation
- Key Solutions for Collaboration and Information Sharing (Coordination and Implementation)
- working model (s)

The design of the project system is started by the subscriber before the key partners of the integrated construction project have been selected. As an organization, the project alliance can also take responsibility for the finalization of the project system.

The project delivery system is a complete solution for the reliable implementation of integrated construction projects. It determines the processes and the ways they work:
- The main processes of the project, their operating principles and the involvement of the different parties in the main processes (the parties have their own established operating models and processes),
- Processed sub-systems arranged as naturally as possible
- Required operational decision-making (definition of key decision-making points)

The project key partners are the main implementer of the delivery system design.
Different project partners are connected to the project implementation via Ring model (Figure 4) where the core (I) present the start of the project with its key partners. This is followed by the outer levels as presented on the following:

I. Main project partners
II. Providers of significant overall solutions. The action concerns the main stages of the project or otherwise a significant part of the project implementation.
III. Key Service Providers with Special Integration Needs for Multiple Project Partners

IV. Service providers with a clearly defined and limited delivery package (such as segregated procurements during the project)

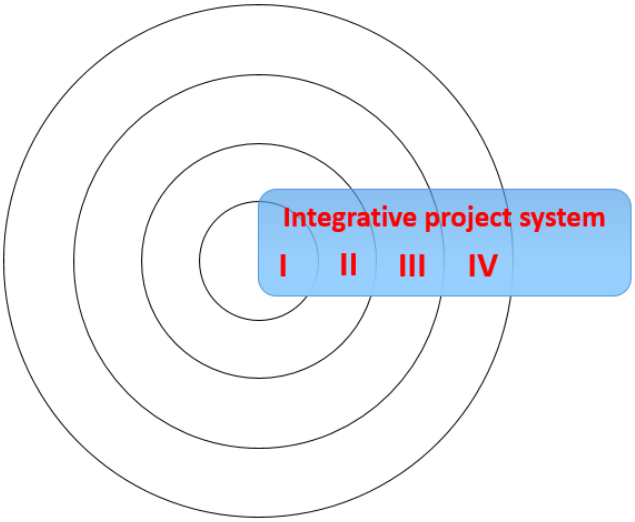

Figure 4: Ring model for integrating different players together for collaborative construction.

4.3 Design of integrative construction project system

An integrating project system contains both generic principles and situational factors. The generic principles and solutions (Lean and Integration Mechanisms) are always the same irrespective of the project in question. Situational factors, which originates from the key partners (client or main service providers), are always designed project-specifically. Therefore, an integrative project system is designed on a case-by-case basis. Integration mechanisms are entities that are comparable to tools and other practical solutions, i.e. key integrating elements. The design of the project system is focused on either the project system or the project delivery system (Figure 5).

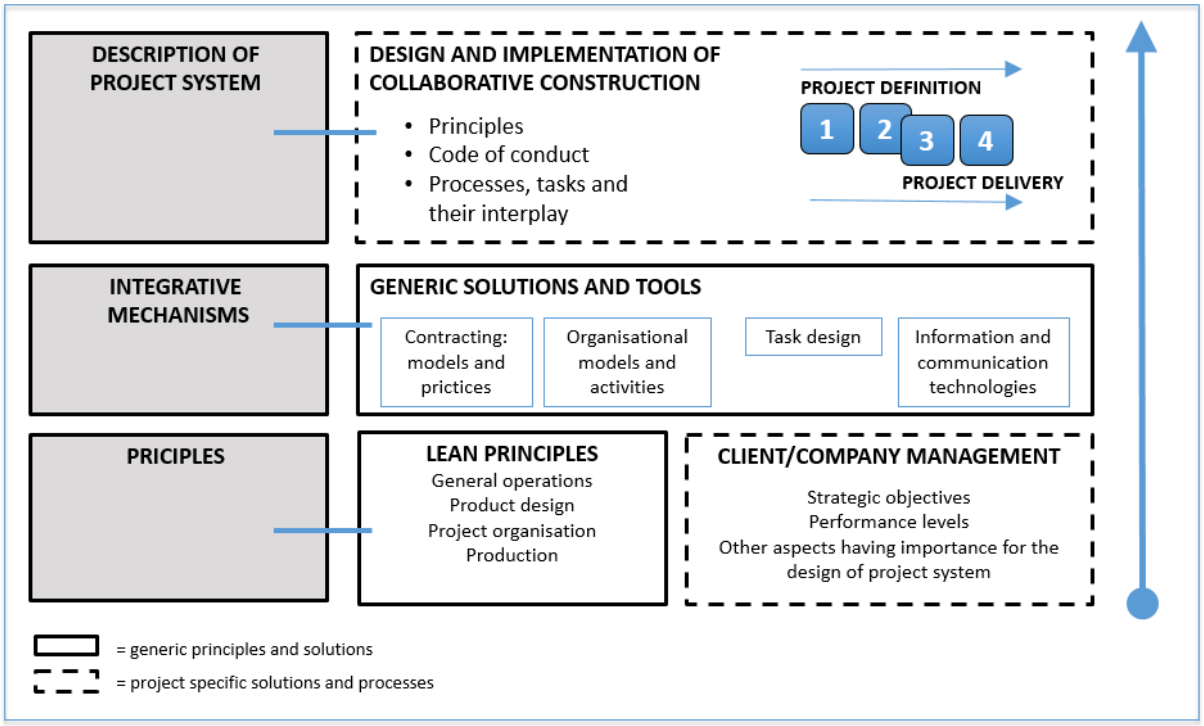

Figure 5: A framework for situation specific design of the integrative project system

5. Discussion

Developed content structuring, a framework for integrative project system, is seen as a basis for guidance and examples for designing situation-specific project systems. This is seen as an element of fundamental importance for the design of collaborative construction projects. The proposed framework is a rather general solution that can contribute to the overall development of broader, better practices in construction implementation.

The solutions presented earlier in this paper and the framework of the integrative project system are essentially based on the lean principles. Their comprehensive implementation and utilization requires the following (Forbes & Ahmed, 2011):

1. A willingness to change
2. Commitment to education and learning
3. Quality thinking
4. A shared vision
5. Commitment to reducing and eliminating waste
6. Commitment to Measuring Cost and Performance
7. The willingness to utilize lean solutions at the design stage
8. Collaboration
9. Effective use of information technology

According to the results of the research, the Lean Principles could be found to be relatively comprehensive in an integrated construction project (Lostuvali et al, 2012). In practice, this means that the lean principles should not be limited to making solutions that are easier to implement, but should seek to be as comprehensive as possible.

6. Conclusions

Project management research and content descriptions (such as APM Body of Knowledge and IPMA Individual Competence Base Line) have to some extent addressed the need for systems thinking in project management. Particularly with regard to the management of demanding and complex projects, systems thinking has often found to be a significant new approach, but its benefits remain unrealized, as there are hardly any practical solutions.

An integrative project system is a new concept that can have fundamental importance for explaining the content and principles of a collaborative construction project. This is to be used as a framework for designing project specific construction project systems. It is proposed that a situation specific project system is to be prepared as a first step for framing the principles and main practices for collaborative construction projects. This forms the basis for more detailed project planning, resourcing and operations. The entity presented in this paper can be described as a first-generation solution that will continue to be complemented and transformed during the next stages of research and development.

Acknowledgments

We would like to thank the partners and sponsors of the RAIN project for their support and cooperation. Those are Consti Oyj, Fira Oy, Granlund Oy, Finnish Transport Infrastructure Agency, Pöyry Finland Oy, Ramboll Finland Oy, Sweco Structural Engineering, Talokeskus Oy, VR Track Oy, YIT Infra Oy, YIT Rakennus Oyj and Oulu University.

References

APM (2012) APM Body of knowledge, Association for Project Management, UK.

Asmar, M.E., Hanna, A.S. and Loh, A.S. (2013) Quantifying Performance for the Integrated Project Delivery System as Compared to Established Delivery Systems, ASCE Journal of Construction Engineering Management (139)

BPIE (2017) Smart Buildings Decoded, Buildings Performance Institute Europe (BPIE), Belgium.

Emes, M. and Griffiths, W. (2018) Systems thinking: How is it used in project management? APM - Association for Project Management, UK, 43 pp.

Eriksson, P. E. (2008) Procurement effects on coopetition in client-contractor relationships. Journal of Construction Engineering and Management, 134(2), 103-111.

Forrester, J.W. (1994) System Dynamics, Systems Thinking, and Soft OR, System Dynamics Review, Summer 1994, Vol. 10, No. 2

IPMA (2015) ICB – Individual Competence Baseline, International Project Management Association, Version 4.0., The Switzerland.

Jørgensen B, Emmitt S. (2007) Integrating Design and Construction from a "Lean Perspective". Proceedings of CIB world building congress 2007, Cape Town, South Africa.

Kerzner, H., 2009. Project management: a systems approach to planning, scheduling, and controlling. 10th ed. Hoboken, NJ: Wiley.

Franz, B., Leicht, R., Molenaar, K. and Messner, J. (2017) Impact of Team Integration and Group Cohesion on Project Delivery Performance, ASCE Journal of Construction Engineering and Management, 143, (1)

Liu, S., Forrest, J.Y.L and Yang, Y. 2015. Grey System: Thinking, Methods, and Mod-els with Applications, in. MengChu Zhou,M.C.Z., Li, H.X. and Weijnen, M. (2015) Contemporary Issues in Systems Science and Engineering, John Wiley & Sons, Inc. pp. 153-224.

Lostuvali, B., Da, T. and Modrich, R-U. (2012) Lean product development at cathedral hill hospital project, 20th Annual Conference of the International Group for Lean Construction, At San Diego, U.S.A.

Masterman, J. and Duff, A. (1994). The selection of building procurement systems by client organizations. Proceedings of the 10th Annual ARCOM Conference, 2, pp. 650-659.

Mills, A., et al. (2011). Infrastructure development using alliances: Lessons and observations. Proceedings of the 27th Annual ARCOM Conference, 911-920.

Ross, J. (2009). Alliance Contracting in Australia: a brief introduction. PCI Alliance Services.

Salminen, J. (2005) Measuring performance and determining success factors of construction sites, Doctoral dissertation, Helsinki University of Technology, 175 pp.

Senge, P.M. (1990) The Fifth Discipline: Art and Practice of the Learning Organization, New York, Doubleday.

Sorri, J., Kähkönen, K. and Rannisto, J. (2013) Construction Business with Innovative Cellular Structures, Modules and Buildings, Proceeding of Organisation and Management of Construction, CIB World Building Congress; Brisbane, Australia, CIB Publication 384, pp. 164-175.

Tadayon, A. (2018) A new look towards relational project delivery models, Thesis for the degree of Philosophiae Doctor, NTNU Trondheim, Norway.

The American Institute of Architects (2007). Integrated Project Delivery, a guide. AIA, US

von Bertalanffy, L. (1968) General System Theory: Foundations, Development, Applications, New York, George Braziller.

Walker, D. H. T., Harley, J. & Mills, A. (2013). Longitudinal Study of Performance in Large Australasian Public Sector Infrastructure Alliances 2008-2013, Melbourne, RMIT University, Centre for Integrated Project Solutions. 38 pp. + app. 7 pp

Walker, D. H. and Lloyd-Walker, B. M., (2015). Collaborative project procurement arrangements.