AALTO UNIVERSITY

SCHOOL OF ENGINEERING

Department of Real Estate, Planning and Geoinformatics

Degree program in Real Estate Economics

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# CHALLENGES IN BUILDING INFORMATION MODELING: Insights from a Pioneering Process Development Workshop in Finland

Master's Thesis

Helsinki, February 24th, 2015

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Instructor's: Teemu Lehtinen, M.Sc. (Tech.) and Matilda Smeds, M.Sc. (Tech.)

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ABSTRACT OF MASTER'S THESIS

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Abstract:

The purpose of this thesis was firstly, to find the challenges related to BIM process, and secondly to find the solutions to the challenges. The solutions were found from multi-party agreements (MPAs), where building construction and the contract is designed in collaboration between the architect, the other designers, main contractor, and the owner. The contract model is based on the fact that the profits and risks during the process are allocated between the participants, which will motivate the team to pursue as effective cooperation as possible, to share information also about incomplete work, and thus to enhance understanding about different discipline's work, challenges and the whole design and construction process. The subject is relevant, as the industry evolves so slowly even though there are solutions for the challenges.

Building information modeling (BIM) refers to the process in which different disciplines are designing 3-4D designs within a construction project. It provides development opportunities when there is competence to utilize them. The model can be used for visualization for the owner and the authorities, and as a tool for the site workers in the constructing phase. The as-built model can also be used in the maintenance phase, as all the materials and particles used in the building are in the final model.

The challenges found during this study were especially related to collaboration, coordination, contractual interests, and the lack of competence in both using the models, as well as the modeling it-self. The results show that these challenges are not only related to BIM, but construction processes in general. Thus, it is important to emphasize all of the most obvious solutions available. This thesis provides for a basis for future research concentrating on operational challenges related to construction process. It also serves the field work, especially in the planning phase, when struggling with the challenges presented in this thesis.

The empirical part of this thesis was based on a focus-group workshop arranged for the Finnish pioneers in BIM, from which the qualitative material was collected by observations and recordings. In the research, an initial theoretical framework is constructed from the BIM related challenges and MPA related solutions found in the literature, which are tested with the collected empirical data. The result is an enhanced constructed framework, which shows that the BIM related challenges can in fact be solved with implementing MPAs as well as the so called Last Planner® System.

Keywords:
BIM, IPD, PA, PP, Last Planner ® System, collaboration, coordination, BIM Competence, data interoperability.

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Tiivistelmä:

Tämän työn tarkoituksena oli löytää tietomallintamisprosessiin, käytäntöihin ja teknologioihin liittyviin haasteisiin ratkaisuja monen osapuolen välisestä sopimusmallista (MPA), missä rakentaminen ja sopimus suunnitellaan yhdessä arkkitehdin, muiden suunnittelijoiden, rakennuttajan sekä omistajan kesken. Sopimusmalli perustuu siihen, että sekä rakentamisprosessin aikana säästetyt varat että siihen liittyvät riskit jaetaan edellä mainittujen osapuolten kesken. Tämä motivoi jokaista tavoittelemaan mahdollisimman tehokasta yhteistyötä, jakamaan tietoa keskeneräisistäkin suunnitelmista, ja parantamaan siten ymmärrystä eri osapuolten työstä, haasteista ja koko suunnittelu- ja rakennusprosessista. Tutkimuksen aihe on relevantti, koska teollisuudenala kehittyy hitaasti siihen nähden, että löytyneisiin haasteisiin on olemassa ratkaisuja.

Tietomallinnus (BIM) tarkoittaa eri suunnittelualojen toimesta tehtävää 3-4D – suunnitteluprosessia samassa rakennusprojektissa. Tietomallia voidaan hyödyntää omistajalle ja viranomaisille visualisoinnissa, työmaan työntekijöiden oppaana, ja niin kutsuttuna to-be – mallina toteutuneesta rakennuksesta. Mallia voidaan hyödyntää myös ylläpitovaiheessa, kun kaikki olennainen on siihen mallinnettu.

Tämän tutkimuksen puitteissa havaittuja haasteita ovat erityisesti yhteistyön optimoiminen ja koordinoiminen, sopimustekniikka, tiedon yhteensopivuus, sekä mallintamisen ja mallien käytön osaamisen puute. Tutkimuksen tulokset osoittavat, että löydetyt haasteet eivät liity vain tietomallintamiseen, vaan rakennusprosesseihin yleensä. Niinpä on tärkeää korostaa kaikkia yleisimpiä, olemassa olevia ratkaisuja niihin. Tämä työ tarjoaa perustan tulevalle, rakennusalan operationaalisiin haasteisiin keskittyvälle tutkimukselle. Tämä palvelee myös kenttätyötä, erityisesti niissä suunnitteluvaiheen haasteissa, joita on esitelty tässä työssä.

Työn empiirinen osa perustuu Suomen BIM pioneereille järjestettyyn fokusryhmä-workshoppiin, mistä laadullinen aineisto kerättiin havainnoimalla ja nauhoittamalla. Tutkimuksessa luodaan ensin teoreettinen viitekehys kirjallisuuskatsauksessa löydetyistä BIM:n haasteista ja ratkaisuista, jota testattiin empiriasta saamalla aineistolla. Työn tulos on testatusta aineistosta rakennettu paranneltu viitekehys, mistä nähdään, että tietomallinnukseen liittyviin haasteisiin voidaan löytää ratkaisu monen osapuolen välisestä sopimuksesta, sekä nk. Last Planner® Systeemistä, koordinaatiota optimoivasta työkalusta, mikä liitetään usein monen osapuolen väliseen sopimiseen.

Avainsanat:

Tietomallinnus, IPD, PA, PP, Last Planner® System, yhteistyö, koordinointi, BIM kompetenssi, tiedon yhteensovittaminen.

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This Master's Thesis is an end-result of magnificent group work around and within the Research Cases and the whole RYM PRE Model Nova work package collaboration, not to forget the supportive criticism and peer evaluation from my research group members Matilda Smeds, Teemu Lehtinen and Saara Matala. We read, and initially heard, thousands of pages of transcripts of experience which the participants offered us in numerous interviews, process simulations and meetings. The cases were not used in this thesis, instead I used our workshop in Aavaranta, which itself was an interesting event for a beginning researcher.

I have had the best work environment that I could have imagined; the best instructors Matilda and Teemu, and supervisor Professor Riitta Smeds, from the SimLab unit at Aalto University, to ensure the quality of this Thesis. The numerous changes in focus, and the iterations that followed the scrutinizing and comments, did their part of the job. The writing itself was done partly at home, partly in SimLab's facilities.

During this longish journey of studying, learning, and experiencing Finnish construction industry's struggling with implementing BIM, I have tested myself as a faculty leaping student, as a research assistant, and as a construction project leader to mention few examples. I got also married in 2000, divorced in 2001, gave birth to my beautiful daughter Eden in 2005, lost my grand mom in 2007, my sister gave birth to my niece in 2012, I fell in love in March 2012, I drunk hundreds of liters of beer; I was proposed by Aleksi 1st of June 2012, and the story of my life still evolves, thank God.

I want to thank especially my colleagues at SimLab, Anne, Matilda, Saara and Teemu, and my boss Riitta, for tolerating my wavering during the writing process; my beloved Aleksi for the fantastic but fable journey; my dear brother for supporting me whenever I needed him; and My Mother Seija, without whom I would probably not have finished my studies at all. Thank You!

I still love You, You know…

Blöösteen

# ACRONYMS

| | |
|---|---|
| **AEC/FM** | Architecture, Engineering, Construction, and Facility Management |
| **AIA** | American Institute of Architects |
| **BIM** | Building Information Modeling and the model itself |
| **BOM** | Build-Operate-Maintain contract [or Life-Cycle-Project (LCP)] |
| **DBB** | Design-Bid-Build contract |
| **DB** | Design-Build contract |
| **HVAC** | Heating, Ventilating and Air-Conditioning |
| **ICE** | Integrated Concurrent Engineering |
| **ICT** | Information and Communications Technology |
| **IFC** | Industry Foundation Classes |
| **IPD** | Integrated Project Delivery |
| **LCP** | Life-Cycle-Project |
| **LPS** | Last Planner® System |
| **MD** | Main Designer, usually the architect |
| **MPA** | Multi-Party Agreement |
| **PA** | Project Alliancing |
| **PP** | Project Partnering |
| **RMPC** | Relational Multi-Party Contracting |

# DEFINITIONS

## ALLIANCE CONTRACTING

"Alliance contracts are defined as an agreement between parties to work cooperatively to achieve agreed outcomes on the basis of sharing risks and rewards. Alliance contracts have the potential to deliver substantial cost and quality benefits without the adversarial relationships common in more traditional contracts."(Clifton et al. 2002) Alliance Contracting is also called Project Alliance in this study.

## BUILDING INFORMATION MODELING

Building information modeling (BIM) is a system approach to design, construction, ownership, management, operation, maintenance, use, reuse, and demolition of buildings. (Smith and Tardif, 2009), which generally uses 3-D, 4-d, real time, dynamic building modeling software to increase productivity (Forbes and Ahmed 2011, p.79).

## COBIM

National Building Information Modeling Guidelines for construction projects. Its aim is to consider sustainable development, energy efficiency, and environmental influence, in addition to ensure conformity of the requirements in all phases of the process. The ongoing development of these guidelines is aiming also to broaden the current guidelines in order to serve BIM orders and production more generally. In other words, the purpose is to produce BIM guidelines for extensive use, for the whole field of construction and real estate. (Senate Properties, 2012)

## FRAMEWORK

A framework is a systematic set of relationship or a conceptual scheme, structure, or system. The purpose of establishing a framework is to guide research efforts, to enhance communications with shared understanding, and to integrate relevant concepts into a descriptive or predictive model. (Jung and Joo, 2011)

## HVAC

Heating, ventilation, and air conditioning. (Thais da Costa Lago, 2005)

## INDUSTRY FOUNDATION CLASSES

The Industry Foundation Classes (*IFC*) is an international, open, neutral and standardized on (ISO/PAS 16739) specification for Building Information Models, BIM. IFC can be used to exchange and share BIM data between applications developed by different software vendors without the software having to support numerous native formats. As an open format, IFC does not belong to a single software vendor; it is neutral and independent of a particular vendor's plans for software development. (Gielingh, 2008)

## INTEGRATED PROJECT DELIVERY

"Integrated Project Delivery (IPD) is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction." (AIA, IPD: Guide 2007)

## LAST PLANNER® SYSTEM

Last Planner® System (LPS) is a subset of Lean Project Delivery System™. It uses process-driven approaches for project control for improving workflow reliability and enabling planners to better match the supply of resources to site demand, resulting in accomplishment of higher percentage of planned tasks. It is based on three to four levels of schedules and planning tools. (Forbes and Ahmed, 2011)

## RYM PRE MODEL NOVA

Research project focusing in processes and business models based on BIM and an operating culture that provide added value and promote sustainability and responsibility across the value network as well as throughout the life-cycle of the built environment.

## VIRTUAL DESIGN AND CONSTRUCTION

Virtual Design and Construction (VDC) is the use of integrated multi-disciplinary performance models of design-construction projects to support explicit and public business objectives. (Fischer and Kunz, 2004)

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# I INTRODUCTION

The purpose of this part is to describe the starting point of this thesis and to introduce the topic. Part I consists of three chapters; Background and Motivation (1), which is divided in two sub-chapters – Background and Motivation in General (1.1) and Research Questions, Motivation and Scope (1.2), Methodology and Research Approach (2), and The Structure and Contents of This Study (3).

## 1 Background and Motivation

### 1.1 Background and Motivation in General

The construction industry is evolving much slower compared to other industries. Nevertheless, the use of information technology in creating designs has been evolving towards creating and using different models such as IFCs (The Industry Foundation Classes), which are integrated from the models created by different design disciplines; the architect, structural engineer, HVAC (Heating, ventilation, and air conditioning.) engineers and electrical engineers. The process of this creation is called building information modeling (BIM). Building Information Modeling is presented as having attributes that strengthen the frameworks for providing efficiency in design and project performance (Olatunji and Sher, 2010). In this thesis, BIM "is not the model but the use of the model." (Eastman et al., 2008)

BIM promises major improvements that overcome the limitations of conventional 2D methods in both design and construction processes. It has been argued to provide also platforms for value integration, robust information sources, simultaneous access to design database, automated quantification, project visualization and simulation, among others capabilities. These capabilities facilitate accuracy, objective risk assessment, comprehensive information management and early integration of cost management principles during design. (Olatunji and Sher, 2010)

The need for some major re-engineering of processes involved in developing a typical construction product has been identified and now the focus is on how this may affect various existing business models, organization structures and project delivery patterns. (Olatunji, 2011) For this reason, multi-party agreements (MPAs) s have been frequently related to projects implementing BIM, and Jung and Joo (2011) also argue that MPA will bring mutual synergy effects when utilizing BIM. There are also many other arguments for adopting

MPAs, also called multi-disciplinary integration or relational multi-party contracting (RMPC, Lahdenpera, 2012), such as decreasing the amount of challenges related to the typical characteristic of construction, i.e. separation or fragmentation between design and production (Joergensen and Emmitt, 2007).

As BIM adoption continues to improve, various stake-holding practices that are involved in developing projects through integrated systems require process models to help them simplify the issues related to multi-disciplinary integration – a direct opposite of what they are used to in fragmented systems. They also need to develop appropriate skills and strategies to service intensive collaboration and other features related to BIM. These are some of the inevitable changes to which organizations must respond in order to generate efficient results when adopting and deploying BIM. (Olatunji 2011)

## 1.2 Research Questions, Motivation and Scope

RYM Oy was established year 2009 to provide strategic high-end competence in built environment (SHOK). PRE-research program (Built Environment Process Re-engineering) is the first of RYM Oy's research programs. It started in November 2010 and continues until the end of year 2013. PRE-program's overall goal is to create New Business Model based on Process Network and BIM in the field of real estate-, construction- and infrastructure. The basis of the development is built on more user friendly conduct, which is supported by BIM during the whole lifecycle of the built environment. PRE-program consists of six work packages in which the possibilities of BIM are studied broadly from many different angles. This thesis has utilized data from Model Nova work-package as described in the empirical part (III).

The goal of the work package Model Nova (New Business Model based on Process Network and Building Information Modeling) is to research the implications of the deployment of BIM in the work of individual as well as in inter-organizational processes. One of the goals is also to develop a BIM based "win-win - model of conduct" for cooperation between different stakeholders in a construction project.

In Model Nova –work package SimLab researches and provides new scientific knowledge on BIM-enabled processes and their management. It applies an action research approach via interventions that apply so-called process simulation workshops. Within the simulation projects the research and development concentrates in decision making processes when utilizing BIM from different stakeholders' angels from both strategic and operative point of view. The aim is to produce concrete conclusions and practical solutions in order to further develop BIM-styled systemic process-innovation's implementation in the field of construction. The author of this thesis is a member of SimLab's research team.

Thus, the purpose of this thesis is to study literature about construction projects which utilize BIM, and to find the most common challenges related to BIM. On the other hand, the purpose is to find solutions for the challenges according to the literature, and in the empirical part to validate and to complement the findings in literature by conducting a focus-group meeting for construction industry specialists with experience in large construction projects utilizing BIM. In addition to BIM, the literature review extends to studying so called Multi-Party-Agreements (MPAs), namely Integrated Project Delivery (IPD), Project Alliance (PA) and Project Partnering (PP), and to MPA-related solutions for BIM related challenges. The solutions found in the literature are then complemented with the solutions from the collected empirical data from the focus-group meeting.

The idea for this thesis emerged during the research cases conducted in spring 2011, as part of one of six work packages of a three year research project called RYM PRE Model Nova. *The author of this thesis* was one of the research team members conducting the research in the construction cases. The research was focusing especially on the challenges related to building information modeling. The challenges observed, and the articles mentioned above, among other literature, inspired to study the relation of MPAs as solution to the emerged challenges in utilizing BIM. Thus, the research questions are:

> *1. What are the main challenges related to construction process when utilizing BIM?*
>
> *2. What kind of multi-party-agreement related solutions for BIM related challenges are there for the future cases adopting BIM?*

*The scope* has been chosen by finding the challenges in construction industry, distinguishing the challenges related to BIM, and finding ways to solve the challenges by researching the solutions that MPAs are offering. There are at least three generally known Multi-Party Agreement types in literature concerning construction industry, namely Integrated Project Delivery, Project Alliance (or Alliance Contracting), and Project Partnering. In this thesis the scope has been set to concentrate in the two first mentioned as they have been studied a lot lately and they have such similarities that makes possible to identify them generally as Multi-Party-Agreements.

### Theoretical starting point of this study

This study has relations to several previous studies: The handbook of IPD by American Institute of Architects (2010) serves as the main source of information about IPD, and the main source for Lean Project Delivery - Method is the book “Modern Construction – Lean Project Delivery and Integrated Practices” by Forbes and Ahmed (2011), which offers a thorough outlook into MPAs. BIM literature review is based mainly on BIM Handbook by Eastman et al. (2008), and Building Information Modeling – A Strategic Implementation Guide by Smith and Tardif (2009), which both give an in-depth understanding of BIM technologies and implementation. In this thesis, also tens of contemporary articles complement the handbooks mentioned above. The most significant ones are related to the benefits of MPAs when utilizing BIM (Lahdenpera, 2011 and Jung and Joo, 2011), and negotiating MPAs (Ashcraft, Jr, 2011). The literature on methodology are from Kitzinger (focus-group meeting, 2005), and Creswell (Research Design, 1994). Olatunji and Sher (2010) offered also an interesting insight to Integrated Project Delivery.

*The objectives* of this study are to find solutions for BIM related challenges found in literature and in focus-group meeting data. The solutions are searched from the collaboration model related to Multi-Party Agreements. The challenges and the solutions are gathered from the literature, and validated or invalidated with the focus-group meeting’s data. The contribution of this thesis is a clear list of current challenges related to BIM, and the solutions which the literature, and finally the empirical data, is offering for the challenges. *The results are* for serving the whole construction industry and people involved in construction projects utilizing BIM.

**Objectives in a nut-shell are as follows:**

1) To construct an initial framework about BIM related challenges and the solutions MPAs have to offer to them according to the literature review.
2) To arrange an expert focus-group occasion, in order to find out the empirical benefits of MPAs, or sharing the risks and results between the stakeholders of the project, when utilizing BIM in Finnish construction projects.
3) To validate the theoretical framework about challenges in using BIM, and the solutions MPAs can serve as well as the contingencies they might bring about during the construction project, by conducting a focus group meeting, or workshop, for Finnish BIM pioneers.

# 2 Methodology and research approach

This study follows the qualitative, constructive research approach which means “problem solving through construction of organizational procedures or models”. (Kasanen et al. 1993, 244) An initial theoretical framework is constructed based on the literature review on the challenges in adopting and deploying BIM, and on the solutions, which multi-party-agreements (MPAs) could offer for them. The empirical research (see PART III) is then conducted by arranging a focus group meeting for specialists in the field of architecture, engineering and construction (AEC) industry, pioneering in BIM. The theoretical framework will be applied in order to interpret the interview data, and the empirical test will validate or invalidate the theoretical framework. The results will be presented as an enhanced framework in PART IV, Findings (chapter 8, table 4).

Focus-group research method utilizes a form of group interview that capitalizes on communication between research participants in order to generate data. Although group interviews are often used simply as a quick and convenient way to collect data from several people simultaneously, focus-groups explicitly use group interaction as part of the method. This means that instead of the researcher asking each person to respond to a question in turn, people are encouraged to talk to one another: asking questions, exchanging anecdotes and commenting on each other's experiences and points of view. The method is particularly useful for exploring people's knowledge and experiences and can be used to examine not only what people think but how they think and why they think that way. Focus group discussion of a questionnaire is also ideal for testing the phrasing of questions and is also useful in explaining or exploring survey results. (Kitzinger, 1995)

Also in constructivist approach, the data is formed through interaction with others (hence social constructivism) and through historical and cultural norms that operate in individuals’ lives. Thus, constructivist researchers often address the “process” of interaction among individuals. They also focus on the specific contexts in which people live and work in order to understand the historical and cultural settings of the participants. Researchers recognize that their own background shapes their interpretation, and they position themselves in the research to acknowledge how their interpretation flows from their own personal, cultural, and historical experiences. (Creswell, 1994)

### The role of the author of this study

The author is working as a research assistant in a research team in one of the most appreciated simulation laboratories in Finland (SimLab), which researches processes in and between organizations. The research group consists of three doctoral students (or researchers) and three research assistants. Before this thesis, the author of this study has taken part in a multi-million euro BIM utilizing construction project's case study as a research assistant collecting and analyzing the data, and finally writing the end report with another assistant of the group, under supervision of the project leader.

The researcher did not actively take part in the conversations during the focus-group meeting but took notes and observed during the whole workshop. She also transcribed and analyzed the gathered data by herself.

# 3 The structure and contents of this study

This Master's Thesis is organized into six parts:

**Part I:** Introduction. The purpose of introduction is to describe the motivation and background of this study, and also the contents of this thesis,

**Part II:** Literature review presents the focal concepts of this study, and the theoretical background of BIM related challenges. Finally the initial theoretical framework will be constructed and presented as a summary of the theoretical part of this study,

**Part III:** Empirical research. The empirical research is conducted in a focus-group meeting for BIM pioneers, organized in spring 2012 as part of Model Nova research project. The chapter will present the research process, and explain the purpose of choosing the methods used,

**Part IV:** Findings presents the novel challenges and solutions found in the focus-group meeting, and they will be reflected through the initial constructed framework resulting in a form of enhanced constructed framework, the end-result of this thesis,

**Part V:** Discussion is the final part in which the findings are discussed and reflected against the literature presented in Part II. Also the need for future research is presented (11.2).

The structure of this study is illustrated in figure 1 below.

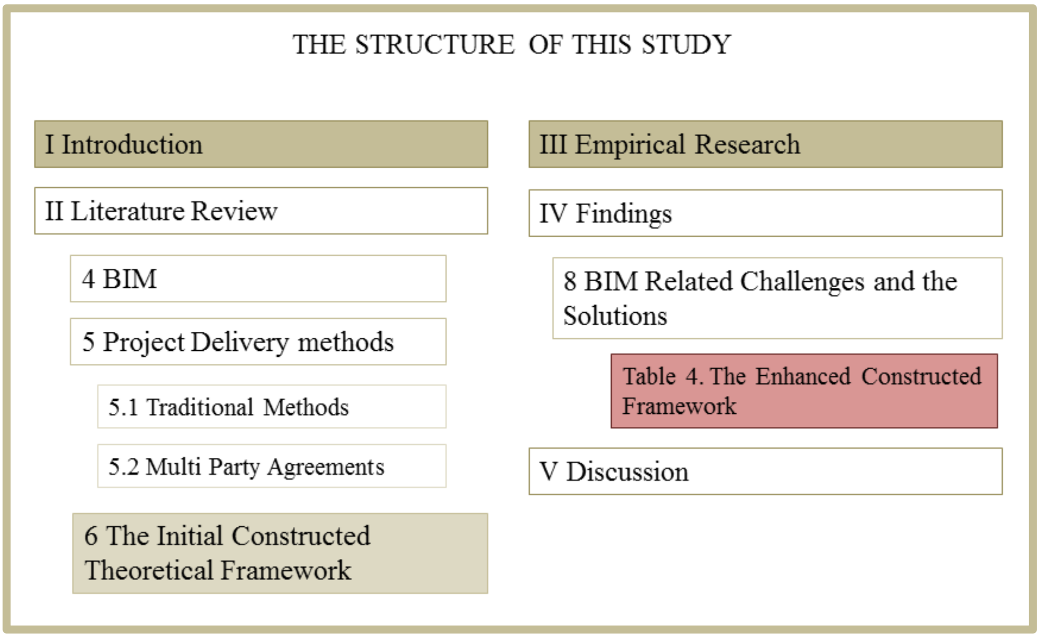


**Figure 1. The structure of this study.**

# II LITERATURE REVIEW

The literature review presents the theoretical background of this study, and consists of three chapters; Building Information Modeling (BIM, 4), Project Delivery Methods (5), and The Initial Constructed Framework (6). The purpose of the part is to review the relevant literature in order to construct a thematic theoretical model which includes the challenges discovered related to utilizing BIM, and the solutions MPAs could offer for them. The model will be used as an introductive framework to be enhanced according to the findings of the empirical research.

# 4 Building information modeling

## 4.1 BIM in general

**Building information modeling**

BIM is not the model but the use of the model a.k.a. the information about the building. (Eastman et al., 2008) It is a system approach to design, construction, ownership, management, operation, maintenance, use, reuse, and demolition of buildings (Smith and Tardif, 2009), which generally uses 3-D, real time, dynamic building modeling software to increase productivity (Forbes and Ahmed 2011, p.79). BIM is associated with Virtual Design and Construction (VDC). It is "the use of integrated multi-disciplinary performance models of design-construction projects to support explicit and public business objectives" (Kuntz and Fischer, 2012), and the business process by which anyone will get easily exchangeable building information about the building throughout its lifecycle. Acronym BIM is frequently used also for the model itself, but in this thesis it is used to describe the human activity that involves broad process changes in construction.

**Who creates BIM?**

BIM allows schedulers to create, review, and edit 3-4D models more frequently, which leads to more reliable schedules. The model is created by integrating the models designed by the architect, HVAC engineers, electricity engineers and structural engineers for each facility representing the model as building geometry, spatial relationships, geographic information, and quantities and properties of building properties. (Forbes and Ahmed 2011, p. 79) Beside the capability to support geometry and material layout, there are structural and energy analyses, cost estimation and scheduling the construction.

In order to jointly contribute to the work at hand, the need to pass data between applications calls for interoperability. It eliminates the need to replicate the work already generated. (Eastman et al, 2008. P. 66) In other words, BIM should advance the data collection and perpetuation, not add the workload (Smith and Tardif, 2009).

According to Azhar (2008) building information model can be used for the following eight purposes:

1) Visualization: 3D renderings can be easily generated in-house with little additional effort.
2) Fabrication/shop drawings: it is easy to generate shop drawings for various building systems, for example, the sheet metal ductwork shop drawing can be quickly produced once the model is complete.
3) Code reviews: fire departments and other officials may use these models for their review of building projects.
4) Forensic analysis: a building information model can easily be adapted to graphically illustrate potential failures, leaks, evacuation plans, etc.
5) Facilities management: facilities management departments can use BIM for renovations, space planning, and maintenance operations.
6) Cost estimating: BIM software(s) have built-in cost estimating features. Material quantities are automatically extracted and changed when any changes are made in the model.
7) Construction sequencing: a building information model can be effectively used to create material ordering, fabrication, and delivery schedules for all building components.
8) Conflict, interference and collision detection: because BIM models are created, to scale, in 3D space, all major systems can be visually checked for interferences. This process can verify that piping does not intersect with steel beams, ducts or walls.

**BIM tools**

The current generation of BIM architectural design tools include Autodesk Revit® Architecture and Structure, Bentley Architecture and its associated products, the Graphisoft ArchiCAD® family, and Gehry Technology’s Digital Project™ as well as fabrication-BIM tools, such as Tekla Structures, SDS/2, and StructureWorks which have all grown out of the object-based parametric modeling capabilities developed for mechanical systems design. While in traditional 3D CAD every aspect of an element's geometry must be edited manually by the users, the shape and assembly geometry in a parametric modeler automatically adjusts to changes in context and to high-level user controls. (Eastman et. al, 2008)

### 4.2 Benefits of Utilizing BIM in Construction Projects

*"The key benefit of BIM is its accurate geometrical representation of the parts of a building in an integrated data environment."* (CRC Construction Innovation, 2007)

#### 4.2.1 BIM is team activity

As the design and construction of a building is a team activity, the best results have been achieved by intense collaboration between the contractors, mechanical subcontractors, and designers in design phase. (Forbes and Ahmed 2011, p.79) As Rizal (2011) phrases it: The main factors for a successful collaboration using BIM can be recognized as "POWER": product information sharing (P), organizational roles synergy (O), work processes coordination (W), environment for teamwork (E), and reference data consolidation (R).

Any planning team should consider at least the following issues when preparing and developing a 4D model; Model scope, reorganizing or customizing the groupings of components, scaffolding, decomposition and aggregation, schedule properties and the level of detail (LoD). Model scope determines the level of detail, which in turn is affected by the size of the model, the time allocated to building it, and what critical components need to be communicated. (Eastman et al., 2008, P. 233)

#### 4.2.2 Benefits to different disciplines

*Planners* can visually communicate the planned construction process to all project stakeholders and the models are often used in community forums to present to laypersons how a project might impact the critical community concerns. The planners can also manage laydown areas (e.g. Site logistics) and coordinate the expected time and space flow of disciplines on the site as well as work in small spaces. (Eastman et al, 2008. P. 225-226)

By using BIM tools, *architects and other designers* are able to provide the contractor for models that can be used for estimating, coordination, construction planning, fabrication, procurement, and other functions, like swiftly adding detailed information into the model. (Eastman et al., 2008. P. 212-213):

The drivers that are motivating *owners* are cost reliability and management, time to market, increasing complexity in infrastructure and marketplace, sustainability, labor shortages, language barriers and asset management. The *owner* will get valuable and understandable information on the current situation of design outcome, and will see the needed changes from the model. The traditional drawings request for some knowledge about how to interpret the designs. BIM on the other hand is a visually more comprehensible product. (Eastman et al., 2008, P.97)

Owners are often faced with cost overruns or unexpected costs, which lead to owners' decision to either over run costs, change the original plan and requirements according to the budget or to cancel the project all together. The accurate and computable nature of BIM offers the owners a more reliable source to take quantity take-off and estimating, and provides a quicker cost feedback in case of planning and making changes. (Eastman et al., 2008, P.97) The model makes also design scenario comparison relatively easy already early in the project. (Eastman et al., 2008, P.99)

Environmental requirements are pressing the owners to consider environmental issues concerning their projects. BIM offers a tool for performing energy analyses. The challenge is to compute the specific effects of the changes made for reducing energy consumption. Nevertheless there are many tools for owners to evaluate the payoff and return on energy-saving investments, including life-cycle analysis. BIM technologies provide owners with tools needed when assessing the trade-offs when mitigating glare and solar heat gain. (Eastman et al., 2008, P. 104-105) Owners who look after the whole lifecycle of the facility can also use the model strategically and effectively to quickly populate a facility management database. These savings are attributed to the reduction of labor needed to enter the spatial information. (Eastman et al., 2008, P. 110-111)

*Field workers*: Projects utilizing BIM usually continue for long periods, and involve numerous service providers. Thus, educating the team through interactive BIM reviews is essential. The visual nature of BIM provides an excellent tool for demonstrating the field workers the work flow and building order. In order to realize the work according to the building information model, the field workers need the ability to read the model. This is achieved by educating the crew. (Eastman et al., 2008, P. 102-103)

Information is generated during each project phase and often re-entered or produced during hand-offs between phases and organizations. The value of this information drops remarkably as it is typically not updated to reflect as-built conditions. A project involving collaborate creation and updating of a building model increases the possibility of duplicate information entry or information loss, which affects dramatically the field, or site crew's work. (Eastman et al., 2008, P. 110-111)

BIM facilitates *leaner* construction processes with direct impact in the way *subcontractors and fabricators* work. At least Eastman et al. (2008, p.262) found the following four impacts:

1) Reduced duration of onsite construction and a shortened product cycle-time from the client's perspective.
2) Priori identification of spatial, logical, or organizational conflicts through step-by-step virtual construction using BIM improves workflow stability.
3) Enhanced teamwork: When construction is performed by better integrated teams, rather than by unrelated groups, fewer and shorter time buffers are needed.
4) When the gross time required for actual fabrication and delivery is reduced – due to faster drawing production – fabricators are enabled to reduce their lead times. This in turn effects easing the taking advantage of pull-flow in fabricators' supply to sites. This eventually reduces inventories of ETO (Engineer-To-Order) components and their associated waste: costs of storage, multiple-handling, shipping coordination etc. And BIM system generated reliable and accurate shop drawings - even when late changes are made – fabricators can be more responsive to clients' needs, because pieces are not fabricated too early in the process.

Post et al. (2010) and Yang and Wang (2009) propose that also the key to Integrated Project Delivery is the use of BIM software, which enables a building to be constructed digitally, and conflicts to be found and resolved well before construction begins.

### 4.3 Challenges in Construction Processes using BIM

The productivity and economic benefits of BIM to the AEC industry are widely acknowledged and increasingly well understood. The technology to implement BIM is readily available and rapidly maturing. Yet, BIM adoption is much slower than anticipated (Fischer and Kunz, 2006). There are two main reasons, technical and managerial. In this thesis, the focus is in the managerial challenges, although the main technical challenges are briefly presented below (4.3.1), before the managerial challenges (4.3.2).

### 4.3.1 Technical Challenges

The technical reasons can be broadly classified into three categories (Bernstein and Pittman, 2005):

1) The need for well-defined transactional construction process models to eliminate data interoperability issues,

2) The requirements for digital design data to be computable, and

3) The need for well-developed practical strategies for the purposeful exchange and integration of meaningful information among the BIM model components.

Khanzode et al. (2012) state, that another concern, which affects the technical challenges, is the creation of the guidelines for the most efficient use of BIM tools in the process of conflict identification. This challenge relates closely also to the need to investigate BIM level of detail (LoD) requirements of various stakeholders for different design and construction disciplines. (F. Leite et al., 2011) Also Lavikka et al. (2012) argue that the integration of the design models has some synchronizing problems when using Industry Foundation Classes (IFC). Computer memory and processing power required for interactive walkthrough, and controlling repetitive construction projects is also one of the major technical issues (E. Elbeltagi and M. Dawood, 2011). Even though the software would offer certain features, the hardware can make changes slow and ineffective because of the time needed for rendering changes.

### 4.3.2 Managerial Challenges

1. Collaboration

The most frequently identified *managerial* challenges are according to the literature, related to collaboration including communications, and document management. (Shen et al. 2008, Mäki et al. 2012) Linderoth (2010) states that the variable composition of design and construction stakeholders involved in construction projects can make effective and efficient collaboration difficult. Xue et al. (2005) argue that AEC industry’s increasingly complicated construction project’s fragmentation occurs in the separation of design and construction, coordination issues between functional disciplines, and insufficient communication. Low productivity, cost and time overruns, and conflicts in the AEC industry are seen to be caused by this fragmentation. (Xue et al. 2005) Lavikka et al. (2012) depicted four sub-processes where different organizations need to collaborate in order to reach the objectives set for the building.

The sub-processes are 1) defining requirements for the building, 2) integrating the different design models into a BIM model, and 3) energy simulations. The fourth sub-process was about model change management which is one of the managerial challenges. The sub-processes represent the reciprocal task interdependencies between the organizations. Also Fisher and Kuntz (2004) state, that the major opportunity for improving the design and construction of facilities exists at the interfaces between disciplines, which, in most cases, represent also different organizations. Thus, efficient utilizing of BIM requires substantial changes in the construction methods and contracting. (Mäki et al. 2012)

Dehlin and Olofsson (2008) argue that in order to reach benefits by using BIM, a shift of focus from cost/benefits for individual stakeholders to costs/benefits for the project is needed. Further, managerial challenges in literature include determining how to organize the project team (Eastman et al., 2011, 26-28), which in turn affects the collaboration during the project.

2. Coordination

Khanzode et al. (2008) adds the question about how to structure the coordination process to best utilize the BIM tools. The creation and organization of the mechanical, electrical, and plumbing (MEP) coordination process using BIM tools (Khanzode et al. 2012) is mentioned also in more general way concerning the coordination during the whole construction process.

3. Contractual interests

Other challenges found in the literature are e.g. aligning the contractual interests of the coordination team to meet the overall project schedule (Khanzode et al. 2012). Contract related challenges include also legal issues such as who owns the document ownership and producing rights. Eastman et al. (2011, 26-28) further emphasizes the need to develop general conducts and information usage, as well as the implementation of BIM in the first place.

4. Data interoperability

Data interoperability (Bernstein and Pittman, 2005) is currently a more broadly noticed challenge. Ashcraft, Jr (2010) expresses the issue as follows: "*If data will be used for multiple purposes, these needs must be considered before information is entered into the models so that the correct information can be extracted… Organizing these details early in the project will increase the effective use of BIM and allow it to be the ultimate collaboration server.*"

The challenges found in literature have numerous solutions as proposed also by many authors in this chapter. Thus, the following chapters will introduce the traditional construction methods alternatives, which according to the literature, increase collaboration, and further develop coordination as well as improve issues related to contracts.

5. BIM competence

There is also a shortage of competent building information modelers in the construction industry (Khanzode et al. 2008), which is considered managerial issue as well. Even if the process is perfect, it needs actors to execute the given tasks. In addition, sub-contractors' have a lack of readiness to use BIM. That is, do sub-contractors have the financial resources to invest in BIM? “One subcontractor claimed that his firm was too small to afford an investment in BIM and said that many projects in which they are involved are also too small to take advantage of it.” These contextual elements cause challenges both for the transfer of knowledge among projects and to the permanent organization**,** as well as for the transfer and diffusion of ICT (Information and communications technology) in general. (Linderoth, 2010)

# 5 Project delivery methods

All existing project delivery methods are not introduced thoroughly in this study. Instead, the differences between the traditional methods and relational multi-party contacting (RMPC, or Multi-Party-Agreement, MPA) are emphasized, as the focus of this study is to find MPA related solutions to BIM related challenges (motivation for this is given in sub-chapter 1.1). In sub-chapter 5.1 the so called traditional project delivery methods are presented in order to gain understanding about the differences and similarities between the traditional and alternative project delivery methods. Sub-chapter 5.2 on the other hand, presents one of the most essential parts of this literature review, multi-party agreements. Integrated Project Delivery (5.2.2) and Alliance Contracting (5.2.3) are presented in detail for further deepen understanding about their relevance as solution suppliers for BIM related challenges.

## 5.1 Traditional Methods

Design-Bid-Build (DBB) contracts and Design-Build (DB) projects are the so called traditional contracts in which owners and designers are in contract with the constructor, and the DB organization assumes responsibility for both design and construction. The constructor takes part in a bid with his/her designer’s preliminary designs, and after awarding completes the designs are used as execution designs. (Arditi et. al, 2002) The other broadly known methods are: Engineer-Procure-Construct (EPC) projects, Design-Construction Management (CM) contracts, Design-Agency CM contracts, CM-at-Risk contracts, Fast-Track Construction, and Partnering or Relational Contracting, which is in the focus of this study by the name MPA.

There are certain features that are common to all traditional project delivery methods. Firstly the owner is often responsible for the choices he/she makes, secondly the contractor can still make hidden choices to avoid costs and maximize profit. The designer is working straight with either the owner or the contractor. The flexibility for changes is limited and the changes are costly. The quality of the building might be jeopardized in order to maximize the profit for the contractor. (Forbes & Ahmed, 2011, p. 8-20)

The uncertainty which relates to demanding projects also emphasize the challenges associated with the traditional ways of construction project realization. The realization of the projects in built environment, and the numerous related stakeholder interests and demanding construction site arrangements are part of the challenge. The earlier you know that you have a problem on your project, the better chance you will have to mitigate that problem. (Fleming and Koppelman, 2002) Also environmental circumstances and uncertainty of the initial data as well as the need to minimize the hindrances during the construction phase are continuous challenges in using traditional methods. (VTT 2471, 2009)

**Keys to project success in general**

1) A knowledgeable, trustworthy, and decisive facility owner/developer
2) A team with relevant experience and chemistry assembled as early as possible, but at least before 25% of the project design is complete; and
3) A contract that encourages and rewards organizations for behaving as a team.

(Sanvido and Konchar 1999, and Forbes and Ahmed 2011, p. 66)

**BIM usefulness in traditional construction methods**

BIM can potentially affect every aspect of a business enterprise. Thus BIM implementation is viewed as an integral part of every business process rather than just an isolated effort related to some isolated tasks. (Smith and Tardif, 2009, p. 89) The use of BIM in a DB firm can be advantageous because early integration of the project team is possible, and expertise is available for building the model and sharing it with all team members. This advantage does not apply when the DB firm is organized along traditional disciplines producing 2D or 3D CAD drawings which are handed-off to the construction group when the design is complete. The building model will have to be constructed after that, which leads to the lost ability to overcome the lack of true integration between design and construction. (Eastman et al. 2008) Also constructability is presumably less of a problem in in the DB delivery system and in partnering than in other, traditional contracts because designers and construction personnel, including subcontractors, are in constant interaction throughout the project (Arditi et al. 2002). Other collaboration supporting approaches are the so called Multi-Party-Agreements, which are presented below.

5.2 Multi Party Agreements

MPAs are one of the core subjects of this study since they are commonly related to BIM. The purpose of this chapter is to study the concepts and simultaneously find the benefits they offer to the challenges in projects utilizing BIM.

Prizing the uncertainty, involved in construction, can be expensive for the client when bidding with traditional methods and the model does not always spur towards the execution desired by the client. (VTT 2471, 2009) Also maximizing value and simultaneously minimizing waste in the project level, is difficult if/when the contractual structure inhibits coordination, stifles co-operation and innovation, and rewards individual contractors for both reserving good ideas and optimizing their performance at the expense of the others. (Matthews and Howell, 2005) Hence, the risk has to be shared between the stakeholders. Mutual bearing of the risks is a way to enhance and make the collaboration between the key participants of the process more effective. (VTT 2471, 2009) Also fostering innovation in construction, stresses the need for closer integration and improved collaboration during the execution of construction projects under requiring circumstances (Scott 2001). Ergo, in order to globally improve project delivery, participants from across the supply chain must collaborate starting at the project outset to exploit the unique process- and product design and execution capabilities of individual members of the team as well as synergistic and collaborative relationships that may be developed within the team. (Parrish et. al, 2007)

In addition, performance in demanding and risky projects could be improved by joint risk management (Pishdad and Beliveau, 2010), which is one of the key elements of multi-party agreements, which are the contracting models called Project Partnering (PP), project alliance (PA, or alliance contracting, AC) and Integrated Project Delivery (IPD). They can also be called relational project delivery agreements (RPDA). (Lahdenpera, 2012)

*Project partnering* has the longest traceable history of the three mentioned MPAs. It originated in 1998 when the first project was conducted by the US Army Corps of Engineers to avoid construction disputes, and was based on joint workshop-practice. (Lahdenpera, 2012) The voluntary arrangement between the owner and the contractor was applied only after the low-bid selection of the contractor to the project (Loraine, 1994). Project Partnering is mentioned here as it is mentioned in literature with IPD and Project Alliancing (see e.g. Lahdenpera, 2012). It isn't thoroughly introduced here, as it isn't a contractual agreement.

In this study the aim is to present the other two MPAs in order to clarify the idea of this research effort of finding solutions to the prevalent challenges in construction projects using BIM. Early involvement of key participants, transparent financials, shared risk and reward, joint decision-making, and a collaborative multiparty agreement are some of the features incorporated in all the arrangements to a varying degree. The main similarities and differences between the project delivery systems are that project alliancing and its follower IPD are both contractual agreements. IPD comes with a surplus of introducing some management approaches, whereas project partnering takes a more conservative approach to work scope and liabilities. (Lahdenpera, 2011) The delivery systems, or methods, the contracting, and the key elements are presented in more detail as follows.

### 5.2.1 Multi-Party Contracting

*"In May 2008, the American Institute of Architects published a new set of legal documents that can restructure relationships among professionals and reformulate the processes of designing and building. These agreements support integrated project delivery, or IPD, a practice model that seeks to overcome construction-industry problems of waste and inefficiency."* (Novitski, B.J, 2008)

One of the most notable aspects of MPA is contracting. To share risks as well as profits between all stakeholders, they need solid contracting in order to get everybody also legally involved and committed. The entire importance of the agreement of the tool of business risk management, and calculation, is based on the validity and enforceability of contracts, in which the legal dimension of enforcement plays a major role. (Rudanko, LTA 3/99) Traditional cooperation of construction project stakeholders is subject to the fulfillment of the contract's terms, and that alone doesn't strive for the improvement of the project performance. (Cheng and Li, 2004) In case of IPD, the contract is signed by all participants (owner, contractor and architect/designer) and the purpose is to allocate the risks and profits in a suitable way. (Ashcraft, Jr, 2011)

Finding the common interests and getting the deal right is the first step in negotiation. The process of jointly negotiating a MPA deepens the stakeholders' understanding of the others' interests. In addition, the MPA expresses each party's commitment to its jointly defined goals. Even though, IPD assumes that work will be performed by the best person for the task, exactly who will do the work may be unknown. However, most IPD agreements will have a task matrix, which identifies areas of both sole and shared responsibility. Most IPD agreements have also some level of joint management by the principal parties. IPD expects the team to develop the most appropriate methods for meeting the owner's goals. This requires flexibility, not specificity. (Ashcraft, Jr, 2011)

Ashcraft (2011) argues that a significant number of the participants will have little IPD experience and will not even understand what IPD is or why IPD works. He suggests having an IPD workshop before any negotiation takes place. The workshop includes explaining what

IPD is, why it works, and how it differs from traditional project delivery approaches. The workshop creates common understanding between the participants, allowing the parties to focus on the issues that will make their IPD agreement successful. "A skilled facilitator with actual IPD experience can streamline the negotiation process and improve the outcome." (Ashcraft, Jr, 2011) The negotiation workflow is shown in figure 2 (below) as Ashcraft, Jr (2011) sees it.

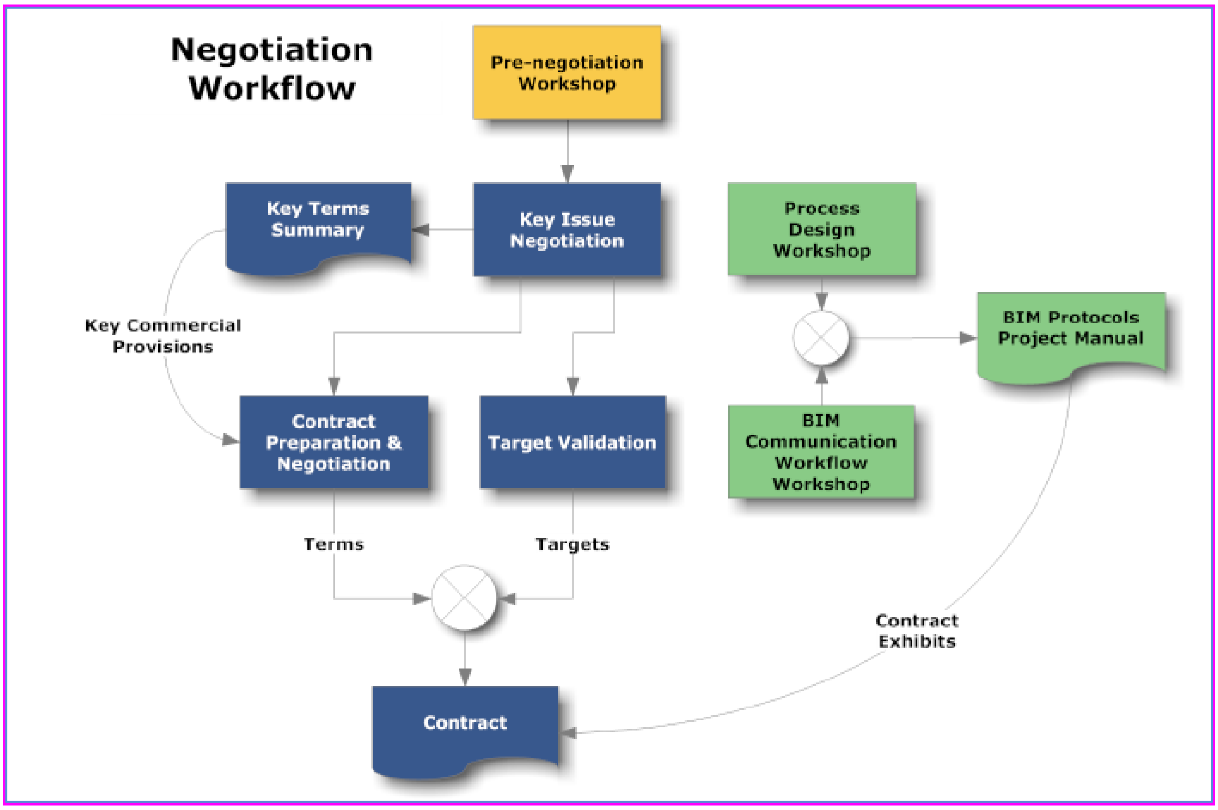


**Figure 2. Negotiation Workflow. (H. W. Ashcraft, Jr. 2011)**

### 5.2.2 Integrated Project Delivery (IPD)

*"IPD is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the knowledge, talents and insights of all participants to increase project value, reduce waste and optimize efficiency through all phases of design, fabrication and construction.*

*IPD uses business structures, practices, and processes to collaboratively use the talents and insights of all participants in the design, construction and fabrication process. Beginning* *when the project is first conceptualized, the integrated process continues throughout the full life cycle of the facilities.*

*IPD principles can be applied to a variety of contractual arrangements and IPD teams can include members well beyond the basic triad of owner, architect, and contractor. In all cases, integrated projects are uniquely distinguished by highly effective collaboration among the owner, the prime designer, and the prime constructor, commencing at early design and continuing through to project handover."* (AIA, The guide, 2007)

The concept of IPD is relatively new, but the convention is not. Already in 2002, the collaboration between the stakeholders has been introduced in detail, even using lean methods. (Freire and Alarcón, 2002) According to Post et al. (2010) an IPD project is carried out by a collaborative team of owner, architect, constructor, and consultants. Also contractors must be involved early in design, and the traditional notions of design phasing change, in order to achieve better, faster, and less-expensive projects. All parties must forego a certain degree of self-interest in deference to project goals, and create a new system of rewards and liabilities.

According to Ashcraft, Jr. (2011) full IPD contract has five major structural elements:

- Early involvement of key participants;
- Shared risk and reward based on project outcome;
- Joint project control;
- Reduced liability exposure; and
- Jointly developed and validated targets.

**Key Elements**

Early Involvement of Participants

Early involvement of participants is the most important IPD element. The participants are the ones that are most valuable for project success. In other words, the ones, that can impart knowledge, which improves the effectiveness, or constructability of the design. Identification of key participants is project specific.

Shared Risk/Reward Based on Project Outcomes

The formulation of shared risk and reward vary between projects, but the principle remains the same. All or part of participants' profit is placed at risk, and "the profit may be augmented if the project outcome is met or exceeded." This principle spurs in unselfish actions instead of participants pursuing their self-interest. It also requires each participant to understand what the objective is, and how it is best achieved. (Ashcraft Jr, 2011)

Joint Project Control

Joint Project Control requires real communication between parties. In order to reach consensus, the participants will have to clearly explain the issues concerned with their work and listen to others' issues. Project management team comprises of at least owner, contractor and designer, and it's authorized to manage the project towards the mutually agreed goals. The level of IPD owner involvement and control is one of the greatest advantages of IPD for the IPD owner. Joint project control is designed to increase parties' commitment to the project as a whole. (Ashcraft Jr, 2011)

Reduced Liability Exposure

In order to increase communication between participants, the liability of each party is reduced. According to Ashcraft, Jr (2011) the fear of liability leads to "bottling up information and a reduction in creativity, performance, and efficiency", and these liability renunciation support communication and creativity by removing this concern. It also advances creativity and reduces immoderate contingencies. Liability waivers also decrease the fear of failure which in turn would decrease the amount of creativity among participants. The waivers also reduce litigation costs. (Ashcraft, Jr, 2011)

Jointly Developed/Validated Targets

Targets are the first act the parties are to deal with during a construction project. The targets serve as metrics for compensation adjustments and as goals for target value design. "Jointly developed and validated targets are the mission statement of an IPD project." (Ashcraft, Jr, 2011)

**Mindshift:**

Trust

According to Ashcraft Jr. (2011) IPD is collaborative, trust-based delivery method. He opines that trust between the participants can be achieved by modeling a transparent financial system, by being able to openly discuss about the goals and concerns, and by placing the team in same location which decreases the possibility of misunderstanding.

Willingness to Collaborate

“The process or mind-set by which all integrated parties involved in a project are willingly doing whatever it takes to work together in concert to, design, construct, and make decisions solely for the good of the project.” (Working Definition, AIA, 2007)

**Catalysts:**

Building Information Modeling

As presented in detail in Chapter 4, building information modeling (BIM) is not the model but the use of the model, in other words the use of the information about the building. (Eastman et al., 2008) It’s the business process by which all participants will get easily exchangeable building information about the building throughout its life-cycle.

Lean Design and Construction

Lean design and construction is presented in detail in sub-chapter 5.2.4 because it is frequently associated with MPAs, and especially IPD. According to Eriksson (2010), the six main elements of Lean design and construction are:

1) Waste reduction
2) Process focus on production planning and control
3) End customer focus
4) Continuous improvement
5) Cooperative relationships
6) Systems perspective.

Multi-Party Agreement

Fostering innovation in construction, stresses the need for closer integration and improved collaboration during the execution of construction projects under requiring circumstances (Scott 2001) In addition, mutual bearing of the risks is a way to enhance and make the collaboration between the key participants of the process more effective. (VTT 2471, 2009) For enabling this kind of collaboration there has been developed contracting models called

Project Partnering (PP), project alliance (PA, or alliance contracting, AC) and Integrated Project Delivery (IPD, presented in detail in sub-chapter 5.2.2) which are called relational project delivery agreements (RPDA) (Lahdenpera, 2012), or multi-party-agreements (MPA), Multi-party agreements (MPA) are presented in more detail in sub-chapter 5.2.

Team Co-Location

Also known as “big-room”- working. Communication is sensitive to physical layouts of workspace. To increase the quantity and quality of interaction, Ashcraft (2011) suggests that the team should co-locate. He states that it builds relationships that create trust, and reduces misunderstanding and stimulates the interchanges that evoke creativity. He stresses that the physical layout of co-location should be built in a way which facilitates and increases the number of useful interactions. In larger projects the state of the collocation layout can be semi-permanent including all the key members of the team.

**Advantages of IPD**

One of the advantages is early co-operation, which increases information flow between the companies involved, and thus reduces the amount of rework in every phase of construction process. The verifiable results concern also the design phase. (Freire and Alarcón, 2002) There is also evidence on successful IPD work. The IPD projects have been produced with tranquility and more collaboration and companionship. They have been finished with high quality, on time and on budget. They have also been completed with no claims. IPD’s collaborative spirit “reduces the likelihood of construction delays”. Most problems are solved by the team before the problems reach the field. (Post et al, 2010) In spite of all, there are still some challenges as far as the contracts are concerned. Team-centric project delivery (or MPA), in which the owner, architect and contractor sign a single contract, is still not consistently defined, understood or practiced. (Novitski, 2010)

According to Cohen (2010), advantages of IPD are:

1) Owners enjoy improved cost control and budget management, as well as the potential for less litigation and enhanced business outcomes.
2) Contractors are provided with the opportunity for stronger project pre-planning, more timely and informed understanding of design, the ability to anticipate and resolve design-related issues through direct participation in the design process, construction

sequencing visualization to improve methods prior to the start of construction, and improved cost control and budget management.

3) For architects and designers, IPD provides more time for design, reduces documentation, allocates more appropriate sharing of risk and reward and improves cost control and budget management.

(Cohen, IPD Case studies 2010)

**Challenges in implementing IPD**

There has been some discourse in the U.S. about the fact that AIA and ConsensusDOCS LLC have come out with model contracts but they are not flawless, and before undertaking IPD projects, the contracts should be closely examined by legal and insurance professionals. Legal structures and insurance policies need also to be reconsidered in order to defer to this new way of collaboration within the construction industry. The first of the three AIA document families maintains conventional relationships between owner, architect, and contractor, but supports information sharing and collaboration. “Liability insurance traditionally has been underwritten and triggered on a basis of claims and fault. But signers of most IPD contracts promise, in writing, not to sue each other or point fingers, which can render liability insurance dysfunctional and inoperative" (Post et al, 2010)

### 5.2.3 Project Alliance

*“In a Project Alliance, the key participants collectively assume responsibility for agreed project performance. The profit (or loss) to each participant is determined by the team’s success in meeting project goals, not individual performance. The shared opportunities and responsibilities align the parties’ interests and provide an incentive for collaboration and blame-free performance. To further enhance the collaborative process, all decisions must be unanimous, disputes must be resolved without litigation and within the Alliance, and compensation is determined on an open-book basis.”* (AIACC’s Handbook on Project Delivery)

In other words also project alliance, or alliance contracting, is defined in literature as an agreement between parties to work cooperatively to achieve agreed outcomes on the basis of sharing risks and rewards (illustrated in figure 3, below). Alliance contracts have the potential to deliver substantial cost and quality benefits without the adversarial relationships common in more traditional contracts. (Clifton et al. 2002)

Project Alliancing mechanism, is developed originally by the British Petroleum in the North Sea, but adopted widely by the Australia's public sector. (Sakal, 2005) It's a method of delivering major capital assets where the owner and non-owner participants work together as an integrated, collaborative team in good faith, acting with integrity and making unanimous, best-for-project decisions, managing all risks of project delivery jointly, and sharing the outcome of the project. (After Department of Treasury and Finance, 2010d)

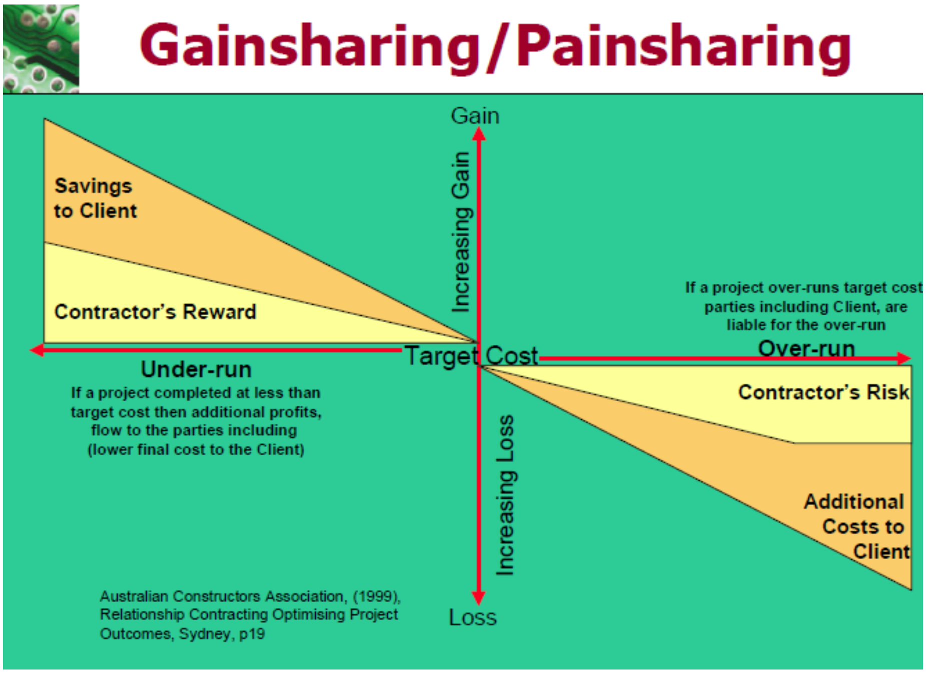


**Figure 3. Relationship Contracting Optimizing Project Outcomes.**

### Structure of an Alliance Organization

All key participants should be represented in alliance organization; or at least client (owner), main contractor, and the main designer. There can be more than one actor per mentioned role, as there usually are when working on bigger projects that require diverse know-how and a lot of resources. One alternative is to build a work consortium by the organizations that are acting the same role, which takes part in the alliance as one project participant. This applies also to multiple contractors, which occurs in projects with high uncertainty and risks. It is in other words clear that the organization is always built for the specific project. On the general level one can only draft the alliance's regime.

Alliance organization consists of alliance management group, project management group, and other project organization. Alliance's key resources come from contract parties: companies and the subscriber. There can be identified also contract parties' top management which takes part in these rare events in which the alliance organization is unable to find unanimous way of resolving some issue.

### Alliance contracts

The way in which the decisions are made is defined in the alliance contract. General principal is that the decisions are made considering the whole project (best for project) All stakeholders have a representative in the managing board (Alliance Leadership Team – ALT) which makes the final decisions concerning the project, usually in an unanimous fashion. The daily errands are conducted by a project group, or Alliance Management Team – AMT, which is led by project manager of the alliance. Forming these groups and deciding on their working practices are agreed upon in the Alliance agreement. Nevertheless they all typically take part in determining project details (e.g. target-cost) and the principles by which project related risks and profits are allocated. (Sakal, 2005)

### Benefits and threats in Project alliancing

Benefits and threats in Project alliancing have been collected by Lahdenpera (2009) as shown in figure 4, below.

| Benefits and opportunities | Weaknesses and threats |
|---|---|
| • Early selection of service providers and cooperation enable relatively quick project implementation | • The cooperation model and shared risk limit the possibility to seek compensation for others' mistakes |
| • Incentives boost realisation of qualitative goals related to interest groups, the environment, society, etc. | • Liability insurance may not cover damage caused by one alliance partner to another in the alliance relationship |
| • The collaborative arrangement promotes transfer of knowledge and learning as well as professional development of staff | • Joint discharge of warranty obligations after implementation is a challenge as the organisation has practically dissolved |
| • The procedure minimises the need of contract management due to changes during work and different interpretations | • Changed roles and close cooperation provide an opportunity for evaluation and recruitment of staff or other companies |

**Figure 4. Evaluating Project alliance. (Source: Lahdenpera 2009, VTT T 2472)**

### Differences between different Multi-party agreements

The differences between traditional project delivery, IPD and AC are collected together, and shown in table 1 as follows.

**Table 1. The Differences Between Traditional Project Delivery, Alliance Contracting and IPD**

| | Traditional Project Delivery | Integrated Project Delivery | Alliance Contracting |
|---|---|---|---|
| **Teams** | Fragmented, assembled on "just-as-needed" or "minimum-necessary" basis, strongly hierarchical, controlled | An integrated team entity composed key project stakeholders, assembled early in the process, open, collaborative | Joint organization. Participants from all contract parties, including the client. Joint decision making . The decisions are made considering the whole project (Best for project) |
| **Process** | Linear, distinct, segregated; knowledge gathered "just-as-needed"; information hoarded; silos of knowledge and expertise | Concurrent and multi-level; early contributions of knowledge and expertise; information openly shared; stakeholder trust and respect | Concurrent and multi-level; early contributions of knowledge and expertise; information openly shared; stakeholder trust and respect |
| **Risk** | Individually managed, transferred to the greatest extent possible | Collectively managed, appropriately shared | An agreement between parties to work cooperatively to achieve agreed outcomes on the basis of sharing risks and rewards |
| **Compensation/ reward** | Individually pursued; minimum effort for maximum return; (usually) first-cost based | Team success tied to project success; value-based | Team success tied to project success; value-based |
| **Communications /technology** | Paper-based, 2 dimensional; analog | Digitally based, virtual; Building Information Modeling (3, 4 and 5 dimensional) | Digitally based, virtual; Building Information Modeling (3, 4 and 5 dimensional) |
| **Agreements** | Encourage unilateral effort; allocate and transfer risk; no sharing | Encourage, foster, promote and support multi-lateral open sharing and collaboration; risk sharing | Alliance contracts have the potential to deliver substantial cost and quality benefits without the adversarial relationships common in more traditional contracts (Clifton et al. 2002) |

Source: AIA (except for the column about Alliance Contracting is captured from sub-chapter 5.2.3, and Lahdenpera 2009). Available online 1.9.2011: http://info.aia.org/aiarchitect/thisweek07/1130/1130n_idp.cfm.

### 5.2.4 Lean Project Delivery System™ as an enabler of Multi-Party Agreements

Lean Project Delivery System™ (LPDS) is presented here as it is often related to especially IPD and is said to support, even if partly implemented, the multi-party contracting system as well as BIM (see e.g. Khanzode et al, 2008, and Yang and Wang, 2009). Lean production focuses on adding value to the produced goods by reducing or extracting unproductive use of time - waste, in the value stream as well as in individual operations. "Lean production adopts a systems view." (Tommelein, 1997) LPDS is presented here in order to explain on what grounds the tools are useful, when it comes to BIM related challenges and the solutions MPAs offer.

## Lean philosophy

The lean production philosophy has provided major competitive advantage at first in Japanese manufacturing companies and later its benefits became known outside of Japan as well. Some of Lean production implementation techniques are: "(1) Stopping the assembly line to immediately repair quality defects; (2) Pulling materials through the production system to meet specific customer demands; (3) Reducing overall process cycle time by minimizing each machine's change-over time; (4) Synchronizing and physically aligning all steps in the production process; (5) Documenting, updating, and constantly reporting the status of all process flows to all hierarchy levels involved. (Tommelein, 1997)

### Lean Project Delivery System™

Lean Project Delivery System™ (LPDS, Figure 5, and Forbes and Ahmed, p. 75) concentrates on workflow throughput in the construction process. Lean improvements are directed to reducing variability in labor productivity instead of output. The concentrating into project level instead of individual tasks is the core of Lean thinking. The relational aspect of Lean is for the strategic management approach to focus on optimizing all stakeholders' performance at the project level instead of seeking their self-interest. (Forbes and Ahmed, 2011, p. 21) There are already several cases in which the implementation of Lean Project Delivery System ™ has been successful (Forbes and Ahmed, p. 79, 81 and 85, and Integrated Project Delivery: Case studies, 2010).

The fundamental to the LPDS is the deployment of the "Five Big Ideas":

1) Collaborate
2) Increase relatedness among all project participants
3) Projects as networks of commitments
4) Optimize the project, not the pieces
5) Tightly couple learning with action

(Forbes and Ahmed 2011, p. 73)

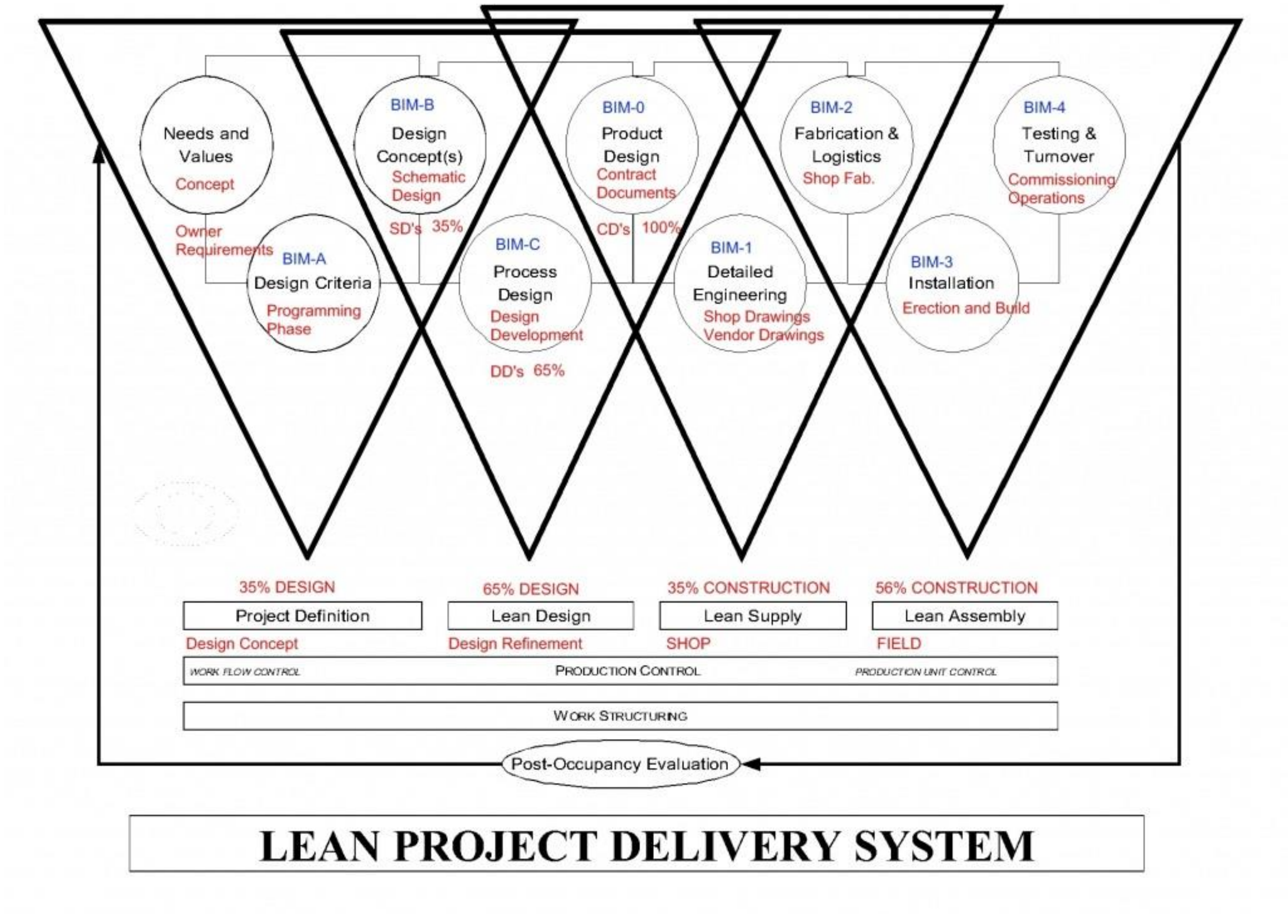


**Figure 5. LPDS, After Ballard, 2008b.** Source: http://bim-modeling.blogspot.com/2011/06/combination-of-building-information.html.

Typical stakeholders of a Lean production include the client (holds the contract; pays the bills), users of the facility, governing agencies (e.g., local building department), designers, fabricators, installers, operators, maintainers, and neighborhood associations. Clients can be multi-headed; e.g., they might include facilities management, engineering, marketing, maintenance, the various groups that will actually use a facility, and possibly more. (Ballard and Zabelle, 2000)

Translating Lean concepts from manufacturing to construction has had some major challenges because of the unique characteristics of the architecture/engineering/construction (AEC) industry and the individual projects, and the geographic diversity among projects. (Tommelein, 1997) The challenges are due to the differences between the production line process and construction process in which the work is not replicable as every construction project is unique. Certain stages are similar from project to project, and thus planning the sub-processes for them can be conducted in order to accomplish as effective way to execute them as possible. Early engagement of key participants along with the implementation of practices such as target costing and set-based design, are practices that have been explored with successful results. (Kemmer et. al. 2011)

**Lean Construction Goals**

The goals are to be achieved by a continuum between designers and constructors and the activities have been identified by Koskela 2000 as follows:

1) Deliver the product
2) Maximize value
3) Minimize waste
4) Lean construction fundamentals
5) Customer focus
6) Culture and people
7) Workplace organization and standardization
8) Elimination of waste
9) Continuous improvement and built-in quality

(The Construction Industry Institute CII, PT 191)

There are many expedients for managing design and production processes. Lean provides the appropriate foundation to cope with those complex management problems inherent to construction projects. (Ballard and Zabelle, 2000b; Ballard, 2008) In this respect, initiatives based on the lean approach to the management and execution of design, that have been developed and implemented to mitigate these problems, are identified. Examples of these include the adoption of the Last Planner System™, Integrated Project Delivery, Target Costing, Set-Based Design, Building Information Modeling (presented in detail in Chapter 4), Value Stream Mapping, Cross-functional teaming, Co-location ("Big Room"), and Early Involvement of Participants. (Kemmer et. al. 2011)

Lean Principles of Design, Construction and Operations are also considered as highly desirable for IPD. Enhanced integration of design and production have been quested and achieved through the adoption of the tools and methods mentioned above. (Parrish et. al, 2007)

Target Value Design (TVD) is an essential part of the Lean construction System (or lean design and construction). It is based on a) designing to an estimate rather than estimating based on a detailed design, and b) building constructability into designs instead of designing first and evaluating constructability later. The basic differences with the traditional and TVD designers' working habits are for the different disciplines not to work in their own offices but in the Big Room in tight collaboration with each other in order not to make which are overpriced, impossible to construct, and which are behind schedule. The lack of collaboration usually results in early, but suboptimal decisions which are difficult to change. (Forbes and Ahmed, 2011, p. 83)

### Advantages in deploying Lean design and construction

According to Forbes and Ahmed (2011) and many other researches, including Freire and Alarcón (2002), there are many advantages in deploying Lean construction. The most remarkable pros are the reliability of workflow, the general cost reductions resulting from reduced time consumption by reducing waste and thus the cycle times, reducing product errors, fewer variations and the share of non–value adding activities, thus increasing productivity by 31%. (Freire and Alarcón, 2002) Compared to traditional construction methods, Lean has reduced 25 % of costs for example in office construction, and schematic design time from 11 to 2 weeks (Forbes and Ahmed, 2011, p. 57). In addition to the above mentioned benefits, in their article, Freire and Alarcón (2002) substantiated that incorporating lean principles in design management with a formal commitment from the organization, and with total involvement of the workers and the administration in the process, the results are substantial.

### Challenges in implementing Lean design and construction

In the beginning of the deployment of Lean construction method or system, there is a notable amount of planning and readjusting to do between the stakeholders in the system. The planning organization will also tack totally different, or at least more, people compared to the planning of a traditional project. The foremen from the field, construction site, and all other stakeholders' representatives are present in the weekly meeting to readjust the next weeks plan according to the actualized work. The allocation of workforce will be different as the optimization of the use of field workers and foremen will be more thoroughly planned. There will also be a need for more constant documentation and control as referred to the Last Planner® System, or its applications. The systemic organizational change will necessitate to evaluate the need for change management issues as well. (Cao et al, 2004)

**Lean applications for planning and coordinating construction**

There are different system variations that support Lean management in construction. In this thesis the Last Planner® System (LPS), a work flow managing tool, is presented in detail as follows.

5.2.5 Last Planner® System

Last Planner® System (LPS) is, according to the literature reviewed in this study, one of the applications offering most usable, and implementable applications when it comes to BIM. LPS uses Lean methods to improve project control. As described by Forbes and Ahmed (2011, p. 86) Last Planner® System is a subset of LPDS™ and is critical to its effective deployment. It uses process-driven approaches for project control which improves workflow reliability and enables planners to better match the supply of resources to site demand, and thus results in accomplishment of higher percentage of planned tasks. The results of a research case conducted in Finland within RYM PRE Model Nova research project in 2012 showed that the implementation of the LP tools brought about positive results in the case organization. "The changes in collaboration involved transitions from formal to emerging agenda, from the use of rule-based tools to the use of new tools, from reactive to proactive temporal orientation, and towards better completion of the design tasks in the design meetings." Also communication between different design disciplines increased during the LPS meetings, and the main designer was able to take an active role in the LPS meetings with the help of the new tools. In addition, the attitudes towards interdependency between design disciplines increased during the process. (Kerosuo et al. 2012)

LPS is based on three to four levels of schedules and planning tools: The master pull-schedule (Level 1), the Look-ahead schedule (Level 2), the Weekly Work Plan (Level 3) and the occasionally needed daily work plan (Level 4). (Forbes and Ahmed, 2011, p. 94) The system is presented in more detail by Forbes and Ahmed (2011) as follows.

Master Schedule (Level 1)

Master Schedule may be used to establish project feasibility and likely duration. It identifies long lead-time items. It also includes infrastructure items based on estimated quantities, estimated craft density, standard rates for labor and labor distribution curves (industry or company based) and the appropriate craft density, in order to complete the work safely and cost effectively. (Forbes and Ahmed, 2011, p. 94)

> Master and Phase planning
>
> This planning occurs in a meeting of project participants or stakeholders. The appropriate steps in the process are: 1. Have an agenda for the meeting, 2. Introduce the entire team so that stakeholders will know each other, 3. Ensure that all required project data are available, 4. Use Post-Its on wall-mounted board, 5. Use a backward/pull approach for assignments, 6. Promote creativity (with controlled chaos) to generate a board cross section of ideas, 7. Identify float (so called workable backlog) and verify with stakeholders, Document the plan (MS Project is an example of software that can be used for this purpose), 9. Review and fine tune the plan. (Forbes and Ahmed, 2011, p. 95)
>
> Reverse phase scheduling
>
> Reverse phase scheduling (RPS) is a starting point for the LPS. This detailed work plan specifies in detail the hand offs between trades for each project phase. In RPS, the subcontractors participate extensively, as projects are generally carried out in assistance of several subcontractors. Their schedules are planned on the wall-mounted board in concert for each work phase. This reverse scheduling starts from the expected completion date as opposite to the traditional push-planning which starts from the beginning of the task and works best with predictable rates of production or cycle time with fixed lead times. The critical path is identified and workable backlog will be introduced to accommodate risk and uncertainty. Reverse phase scheduling and master schedule work as an indicator for what *should* be done in order to meet the schedule. (Forbes and Ahmed, 2011, p. 95)

Look-Ahead Schedule (Level 2)

The purpose of look-ahead schedule is (Ballard and Howell 2003 by Forbes and Ahmed, 2011) to shape the sequence and rate of work flow, to match work flow and capacity, to maintain a workable backlog and to develop detailed plans for how to perform the work. The Look-ahead schedule is as indicated, derived from the phase plan and is used for work flow control. The major items are pulled from and completed for the milestone dates in the master schedule. The work activities that CAN be done are identified within the constraints that have been indicated which reduces uncertainty in the work flow. The look-ahead schedule includes constraints analysis (of production aspects of projects, in design, fabrication or construction), the ADM and first run studies. The trade foremen (last planners) are asked what can be done when it comes to weather conditions, availability of crews, availability of materials, and completion of prerequisite work. The timeframe for look-ahead schedule could be from 6 to 8 weeks, and in the case of design work 3 to 12 weeks duration. (Forbes and Ahmed, 2011, p. 96-97)

The supervisors that are tasked with supervising the schedule manage, develop and maintain the schedule. If there is any discrepancy between the look-ahead schedule and the level 1 Master schedule, then re-planning is done to bring them in line with each other. The project team reviews the upcoming items each week in order to identify any constraints and to make sure they can be carried out in planned timeframe.

“Look-ahead items should meet the following criteria:

1) Manageable size: Schedule items are small enough so they can be detailed to show downstream tasks that prompt work release
2) Readily measurable: Progress and remaining durations should be measurable
3) Free of constraints: It should be made clear where those constraints that have not been resolved are so as not to obstruct the work flow”

(Forbes and Ahmed, 2011. P. 97)

Weekly Work Plan (Level 3)

WWP is derived from the Look-ahead plan. The items that are eligible, with no constraints and with the work force and other resources available and assigned, and that must be initiated to meet the completion dates in that schedule, are pulled from the Look-ahead plan. The plan is laid out after enhancing the level 2 activities into a detailed plan by the responsible supervisors by geographic area and the materials, sequence, and tasks are listed for each area. The documentation of best practices for installation may involve using a library of standard processes which are developed and improved over time. Level 3 activity contains work packages for physical/geographic boundaries. They are managed, rapidly re-planned by foreman when change occurs, and then updated quickly and accurately for completion. (Forbes and Ahmed, 2011, p. 98)

In the next chapter the theoretical background will be integrated into an initial constructed theoretical framework in order to answer the first two research questions of this thesis.

# 6 The Initial Constructed Theoretical Framework

In this chapter the literature review is summarized and the first research question is answered according to the literature, in a form of the initial constructed theoretical framework (Table 2, below). Question 2 is answered, and also complemented according to the reflection of empirical data in the enhanced constructed framework in chapter 9 (Table 4, in part IV, Findings).

The research questions of this thesis were:

1. What are the main challenges related to construction process when utilizing BIM?
2. What kind of multi-party-agreement related recommendations for BIM related challenges are there for BIM-enabled design and construction projects?

The initial constructed theoretical framework combines BIM related challenges, and the solutions MPAs have to offer for them, found in the literature review (Part II). The challenges are divided into five themes, according to their relevance and importance. The importance is based on the amount of literature discussing the subject. The model will be used as a framework for reflecting and analyzing the findings of the empirical research of this study. The five main themes of the challenges, namely collaboration, coordination, contractual interests, data interoperability and BIM competence, are presented below with the solutions.

**1. Collaboration**

The most frequently identified theme of challenges is related to collaboration including communications, and document management. Shen et al. (2008) and Mäki et al. (2012) found, that the expectations and benefits of using BIM are not completely attained resulting particularly from different problems related to collaboration and working practices. Dehlin and Olofsson (2008) argue that in order to reach benefits by using BIM, a shift of focus from cost/benefits for individual stakeholders to costs/benefits for the project is needed. Cheng and Li (2004) also argue that, because all parties are treated equally in the context of partnering, they are encouraged to share information and knowledge. Thus, Lahdenpera (2012) suggests multi-party agreements (IPD, PP and PA) for a solution for this challenge. Traditionally teams are formed through tendering, according to the bids. Multi-party agreements and the principles of forming teams within them differ, as the functionality is the principal criteria of choice, when forming MPAs. Mäki et al. (2012) propose also LPS system as a solution for this challenge, and it is also tested in some construction projects within Model Nova research project, which are still ongoing. In addition, Forbes and Ahmed suggest early decision making, frequent meetings, Weekly Work Plan (part of LPS), and accordingly conducted control, for solving this challenge.

Also following aspects are to be considered: The negotiation process is the IPD team's first collaborative effort and will deeply influence its ability to smoothly collaborate during the project (H.W.Ashcraft, Jr, 2010). The smooth implementation of MPA requires that the modeling accuracy will have to be decided to some extent already before tendering starts, and to be agreed upon when the planning begins (H.W.Ashcraft, Jr, 2010, AIA, 2007). As mentioned, for example LPS will offer the tools for these procedures (Mäki et al, 2012).

### 2. Coordination

The second theme of challenges found in the literature is about organizing the project team, and structuring the coordination processes to best utilize the VDC (virtual design and construction) tools. (Khanzode et al. 2008) Khanzode et al. (2008) also argue that one of the challenges related to coordination is about the creation of the guidelines for the most efficient use of BIM / VDC tools for the process of conflict, which can also be a technical challenge when it comes to integrating the models in to an IFC (Industry Foundation Classes) model. Lavikka et al. (2012) argue that the current amount of reciprocally interdependent tasks can be reduced by attenuating uncertainty in the process. This in turn enables higher degree of standardization, and consequently more effective coordination.

Mäki et al. (2012) allege, that one of the major challenges in the early phases of the project is related to distribution of labor, that is, how to choose the design team, and the individuals who are responsible for the task completion for each discipline. In addition, according to Lavikka et al. (2012), in order to attain the higher level of standardization to the design and construction project, the team should define specific goals for BIM usage during the process, to specify the contents of the models, and to define the process for integrating the models.

As far as the solutions are concerned, MPA's include the guidelines in which all participants are engaged already in the early phases of the project. And for that reason, Forbes and Ahmed (2011) state that especially early involvement of participants as well as early and joint decision making, which are, according to literature, closely associated with MPAs, are solutions to this challenge. Forbes and Ahmed (2011, P. 86) also profess that LPS uses Lean methods to improve project control, and already Ballard (2008) proposed that, Lean provides the appropriate foundation to cope with complex management problems inherent to construction projects. Also Smith and Tardif (2009, P.106) propound that BIM implementation success depends on how well the workflow and information flow is streamlined.

### 3. Contractual interests

Third BIM related theme of challenges is contractual interests. Khanzode et al. (2012) argue that there is a challenge in aligning the contractual interests of the coordination team to meet the overall project schedule. Lavikka et al. (2012) and Mäki et al. (2012) allege, that it should be ensured that the different parties are willing to cooperate, i.e., the contractual, liability, and incentive issues are aligned. This in turn, would increase the different project participants' motivation to execute and commit to increasing standardization in the process.
Another challenge affiliated to the context was about understanding the impact of the design changes in the overall budget (Kemmer et al. 2011). According to Ashcraft, Jr (2010) the changes, and their effects to the budget, should be unambiguously mentioned in the contract. He also argues that construction contingencies can be smaller in a well-drafted IPD agreement, and that as a result from IPD agreement, the amount of rework will be decreased, and time management will become more developed.

IPD agreements are, as mentioned before, signed in the very early stages of the project, and they will bind until the end of the project. (H.W. Ashcraft, Jr, 2010) In order to accomplish the alignment of the contractual interests, all project stakeholders should be involved already in the contract negotiations and project planning. This so called joint decision making, as well as willingness to cooperate are acknowledged elements of IPD (AIA, 2007), which is one of the MPAs, and thus clearly one of the solutions for the contractual challenges found in the literature.

### 4. Data interoperability

Fourth BIM related theme of challenges found is data interoperability issue (Bernstein and Pittman, 2005). Fisher and Kuntz (2004) state that major opportunity for improving the design and construction of facilities lies at the interfaces between disciplines. This refers to all actions e.g. information and knowledge transfer, as well as integrating the models. According to the literature, the data to the models should be entered only once during the building or information life cycle by the most authoritative source. This would in the case of using project bank for keeping the models in use, mean that a responsible person chosen among each discipline makes the transfer of the changed model (Smith and Tardif, 2009. P. 90). Smith and

Tardif (2009. P. 93) also argue that one of the solutions would include integrating the data entry and data maintenance tasks into firm's business processes. In addition, they (2009, p.97) suggest adopting open standards when possible to diminish these challenges.

Other authors also argue, that IPD related solutions are related to early involvement of participants, which will enable knowledge sharing also about needed information technology (IT). Sharing the profits, part of which is one of the key elements in the MPAs, will increase the willingness to invest to the needed IT within the project. As a result the data will be available for all stakeholders in real-time and thus it will keep data accurate and processes between different disciplines smooth. (Fisher and Kuntz, 2004) Data interoperability issues are to be concluded already when forming the MPA team. Also web-based collaboration and project management systems followed by integration of software tools across the project lifecycle are proposed by Shen et al. (2008).

## 5. BIM competence

Lack of competence and skills (or know-how) is also one of the most noticeable BIM related challenges. Lack of BIM skills among the participants during the whole life-cycle of the project, is mentioned in many articles. E.g. Palos (2010) and Niemi (2011) suggest ensuring, "that the process participants possess the necessary capabilities to attain the specific goals for BIM usage during the project". Lavikka et al. (2012) state also, that if the project participants are lacking capabilities using BIM, they should be trained to make their work more fluent, and to prevent errors in modeling and information retrieval. They also argue that the participants should be equipped with an understanding of the whole process to thoroughly understand their own role in it. Linderoth (2010) also emphasize the sub-contractors lack of readiness to use BIM. They do not necessarily have the needed resources for the BIM tools e.g. software. This will result also in lack of transfer of knowledge among projects as there is someone else than the sub-contractor modeling their part. (Linderoth, 2010)

The literature states that "BIM-savvy people will be in high demand, and entry-level professionals will be expected to have much higher level of technical knowledge." (Smith and Tardif, 2009. P. 101) Eastman et al., (2008, Pp. 102-103) argue that educating the team through interactive BIM reviews is essential. They also argue that the visual nature of BIM provides an excellent tool for demonstrating the field workers the work flow and building order. In order to realize the work according to the building information model, the field workers obviously need the ability to read the model. This is achieved by educating the crew. (See e.g. Lavikka et al. 2012)

In addition, all new-ways of working in general require educating the crew, which in this context, refers to employment of new project delivery methods such as IPD, PP and PA, or workflow management tools, such as LPS, which uses Lean methods to improve project control (Forbes and Ahmed, 2011. P. 86).

**Table 2. BIM Challenges and the Solutions - The Initial Constructed Theoretical Framework**

| BIM related challenge | Solution according to the literature |
|---|---|
| **1. Collaboration:** | • Multi-party Agreements (IPD, PP and PA) include the guidelines in which all participants are engaged. (Lahdenpera, 2012) |
| a) How to communicate effectively | • Management protocol should be set: The transparency regarding the goals to be achieved, the rules and responsibilities of each member, the clarity of the status of the development as it evolves and the level of commitment of each team member are fundamental for a supportive environment. (Kemmer et al. 2011) |
| b) How to organize the document management. (Shen et al. 2008 and Mäki et al., 2012) | • Modeling complex requirements, and transforming the complex requirements model into a system architecture, is suggested for accheaving functioning collaboration. (Arayici et al, 2007) |
| c) How to make the team members understand the impact of the design changes in others' work (Kemmer et al. 2011) | • The participants should be equipped with an understanding of the whole process to thoroughly understand their own role in it. (Lavikka et al. 2012) |
| **2. Coordination:** | •MPAs are suggested, as they include the guidelines in which all participants are engaged |
| a) How to organize the project team, and structure the coordination processes to best utilize the VDC (virtual design and construction) tools. (Khanzode et al. 2008 and 2012) | • The implementation of LPS, is perceived important in dealing with uncertainty in the course of design development (Kemmer et al, 2011). |
| b) How to create the guidelines for the most efficient use of BIM / VDC tools for the process such as conflict identification. (Khanzode et al. 2012, Mäki et al., 2012) | • The generation of a considerable amount of extra information at an early stage must have contractual support. (Kemmer et al. 2011)<br>• Modeling the complex requirements, and transforming the complex requirements model into system architecture, is also one of the solutions. (Arayici et al, 2007)<br>• Management protocol is to be set. |
| **3. Contractual interests:** | • Project events that justify changes to targets and profit , as they will reduce the need for any construction contingency. Thus, construction contingencies can be smaller in a well-drafted IPD agreement. IPD also decreases the amount of rework. (Ashcraft, Jr, 2010) |
| a) How to align the contractual interests of the coordination team to meet the overall project schedule? (Khanzode et al. 2012) | • In order to accomplish the alignment of the contractual interests, all project stakeholders should be involved already in the contract negotiations and project planning. This so called joint decision making, as well as willingness to cooperate are acknowledged elements of IPD (AIA, 2007), which is one of the MPAs, and is clearly one of the solutions for the contractual challenges found in the literature.<br>• Target Costing, Value Stream Mapping, LPS, and the clear definition of customers' values and expectations, and the changes, and their effects to the budget, should be unambiguously mentioned in the contract. Kemmer et al. (2011) |
| b) Who are responsible for the task completion for each discipline? (Mäki et al. 2012) | • LPS includes the so called foreman-system in which the responsibles, which are also the messengers between the meetings and the site, are chosen from the crew of each discipline |
| **4. Data interoperability:** | The major opportunity for improving the design and construction of facilities lies at the interfaces between disciplines (Fisher and Kuntz, 2004). Thus, the solutions proposed include |
| a) The need to investigate BIM level of detail requirements of various stakeholders for different design and construction disciplines. (F. Leite et al., 2011) | • Well-defined transactional construction process models (Bernstein and Pittman, 2005), |
| b) How to organize information and knowledge transfer? | • Joint decision making (Forbes and Ahmed, 2011) and |
| | • Adopting open standards when possible (Smith and Tardif, 2009. P. 97). |
| | MPA related solutions are related to |
| | • Early involvement of participants, which will enable knowledge sharing also about needed information technology (IT). |
| | • Sharing the profits will increase the willingness to invest to the needed IT within the project. As a result the data will be available for all stakeholders in real-time and thus it will keep data accurate and processes between different disciplines smooth. (Fisher and Kuntz, 2004) |
| | • Data interoperability issues are to be concluded already when forming the MPA team. Also |
| | • web-based collaboration and project management systems followed by integration of software tools across the project lifecycle are proposed. (Shen et al. 2008) |
| **5. BIM Competence:** | MPA related solutions are related to |
| a) BIM know-how (Lavikka et al., 2012 and Mäki et al. 2012) | • Early involvement of participants, which will increase learning about others' work |
| b) Sub-contractors' lack of readiness to use BIM (Linderoth, 2010). | • Joint decision making (Forbes and Ahmed, 2011), |
| | • Educating the team through interactive BIM reviews, as it is essential for demonstrating the field workers the work flow and building order. (Eastman et al., 2008. P. 102-103 and Lavikka et al. 2012) |
| | • Also new roles such as BIM consultant, construction consultant, or life-cycle consultant might be needed, as "BIM implementation success depends on how well the workflow and information flow is streamlined." (Smith and Tardif, 2009. P. 106). |

# III EMPIRICAL RESEARCH

This part describes the empirical research of this thesis. It consists of Empirical data, which includes 7.1 Data analysis method, and 7.2 Presenting the Data. The overall purpose of this part is to describe which kind of data was collected, how it was collected and how it was analyzed before presenting the findings of this study in part IV. The findings will be based on validating or complementing the initial framework with the empirical data by conducting a focus-group meeting for BIM pioneers from Finnish construction industry.

# 7 Empirical data

In this study the used research methods consisted of constructive method using a focus-group method in collecting the empirical data. The empirical data on the other hand was gathered for validating or invalidating the findings presented in the initial framework, which also determined the themes in which the empirical data was compartmentalized when analyzed.

The quotes of the discussion sessions are presented in the following sub-chapter (7.1), and discussed after each quote separately according to each theme. The purpose of the quotes is to present the empirical data that relates to the focus of this study. The data is categorized by the five themes from the initial constructed theoretical framework in order to more easily compare the solutions found in literature with the solutions found in the empirical data. The actual comparison is made in the enhanced constructed framework (see chapter 8, table 4).

## 7.1 Data Analysis Method

The collaborative BIM development workshop was arranged for Finnish BIM pioneers in spring 2012. The purpose of the meeting was to find solutions to challenges in BIM process, and to construct an ideal model for a construction process conducted in a multi-party agreement setting. In the data analysis phase, the process model was used first and foremost for understanding the consequences of each action, and in locating the recorded data using the chronology of actions, which it presents. The model also presents the solutions to the BIM related challenges, according to the consensus within the focus-group. The group consisted of specialists witch represent following roles in their everyday life: Main constructor, owner, architect, structural engineer and construction consultant.

The meeting was arranged during three consecutive days, of which endured from nine in the morning till four pm. During the days, there were at least two coffee breaks, and a lunch. The sessions were entirely recorded, and the data was analyzed by choosing the relevant parts of the discussion in the focus-group meeting according to the challenges found in the literature. The purpose was to collect data which will help in answering the research questions.

The focus group meetings data was categorized by the themes which were presented in the initial constructed theoretical framework, and the parts, where the discussion either validated the challenges and solutions presented in the initial framework, or defaced the findings into a new setting, are presented in the enhanced constructed framework (chapter 8, table 4).

### 7.1.1 Background of the workshops

For this empirical inquiry, Alpha construction specialist workshop was arranged as part of RYM PRE Model Nova research project in Alpha. The purpose of the meeting was to create new process model for future construction projects which utilize building information modeling during the whole life span of the building. The participants are all part of Model Nova consortium.

### 7.1.2 Focus-group Method and the Research Process

The challenges in using BIM were initially gathered during the literature review. Then empirical workshops were arranged in order to validate or invalidate the findings. The data collection was conducted in focus group meetings which were arranged and facilitated by SimLab’s researchers in Alpha in 30.1.2012-1.2.2012. The idea behind the focus group method is that group processes can help people to explore and clarify their views in ways that would be less easily accessible in a one to one interview.

The group of research participants consisted of 30 people which were divided into three smaller groups, each with key-participants from all disciplines commonly present in construction projects. The ideal group size in a focus-group is between four and eight people (Kitzinger, 1995). In Alpha’s case the group size was seven, unless the researchers are also counted, in which case the group size was ten. Sessions may last one to two hours, or extend into a whole afternoon or a series of meetings (Kitzinger, 1995) as it did in the workshop in Alpha. The chosen group was formed choosing participants from different disciplines of AEC industry, in order to have representatives giving different perspectives to the discussion.

During the three day event there were five sessions for each group in addition to two sessions for all three groups together. All of the groups had different topics or themes to work with during the three day workshop, although the topics or themes were all related to the challenges in utilizing BIM in construction projects, as mentioned before. This thesis will concentrate on the group work of group three, as the group concentrated on constructing an ideal process chart for MPA construction projects implementing BIM, which is a fruitful setting when it comes to collecting data about analyzing BIM related challenges and the solutions for them. The author of this thesis took also part in it in the role of a researcher.

The participants of the group represented all disciplines that generally take part in construction projects utilizing BIM, except a geological engineer: In addition to two architects, the group consisted of a construction specialist, construction consultant, a structural engineer, BIM expert, and two constructors. One of the constructors was representing public sector, as a constructor, working for a Finnish government owned real-estate company, with a background of an architect, and broad expertise across disciplines. The other one represented private sector, with a background of a construction engineer. The group also included three researchers, two from SimLab, Aalto University, and one from CRADLE, Helsinki University.

**Table 3. Members of the Focus Group**

| | |
|---|---|
| Researcher | **3** |
| Construction specialist | **1** |
| Architect | **2** |
| Construction consultant | **1** |
| Structural engineer, development specialist | **1** |
| Building information modeling expert | **1** |
| Constructor | **1** |
| Main Contractor | **1** |

The workshop started on Monday during which the group dynamics was created, and mutual understanding about the initial topics and the desirable results were generated by discussing the topic one person at the time. The days included one coffee-break before lunch, lunch, and an afternoon coffee. The coffee-breaks were arranged according to mutually made decision about when it best suited to interrupt our discussion.

The group had a task to build up an ideal process for the collaboration in a MPA project. During the first working day the group listed the points of value creation during the process, and the discussion was very technical most of the time. On the second day the group started to build the process chart on a four meters long wall. The discussion started chronologically from the phase where the need for the whole project was distinguished by the owner of the project, after which the conversation gyrated a lot in time. In the end of the day, the accomplishments were shown to the other groups. The presentation was held by one of the group members while the other group three members were listening to the accomplishments of other groups'.

The work continued by discussing the most critical points during the process e.g. when to make different decisions, or who is responsible for arranging team meetings. The workshop continued for two more days, and ended after the process chart was ready. The chart included the whole life-cycle of a construction project. For this thesis, the chart was used only as a reminder in order to browse the recorded material and for finding the comments relevant for this study more easily whenever needed. The results of the focus-group meeting are presented in the enhanced constructed framework/model, in column named "Empirical Solutions".

The group sessions were facilitated by a researcher from SimLab, who only interrupted when the discussion got stuck or went out of focus. She also put the activities and the related comments to the wall during the sessions. The other researcher, the author of this thesis, wrote notes and asked some additional questions to clarify the comment's point, in case she didn't understand the message correctly, and thought that maybe someone else didn't either. The third researcher also asked questions that helped him to get more detailed answers to some already discussed topics, which relate to his research.

In this case it was best to take along a series of blank cards and fill them out towards the end of the session, using statements generated during the course of the discussion. Researchers of the group also involved the group in recording key issues on a flip chart and on sticky paper slips, of which the "ideal multi-party construction process chart" was constructed.

The group discussions were tape recorded and transcribed, consisting only the relevant parts of the discussion. Thus, analyzing the focus group, the researcher drew together the discussions of the group.

## 7.2 Presenting the Data

### Theme A: Collaboration

Collaboration, to work one with another, was one of the key issues during the workshop. The project delivery method in focus was multi-party agreement, which itself involves a contractual agreement between key participants instead of only the main contractor and different disciplines, as well as other involved stakeholders. The workshop followed the chronological order of a construction process, and the discussion included the changes and benefits, which result from conducting a project in multi-party agreement.

### Co-location

As the projects in Finland are relatively small, the possibility to collocate through the whole project is minimal. Instead frequent, regular meetings were suggested by the Construction Counselor:

- *"Could, in some schedule, the owner organize a space where there should be internet connection and all, where they could work regularly? Should it be once a week or something?"* (Construction Counselor)

The BIM specialist had already used team work in colocation in many projects. The main contractor, and employer for which the BIM specialist was working, offered a space for their teams meetings, and as the meetings increased participants' understanding about each-other's work, and the consequences which ones work caused to other's work, thus the work came more easily optimized within the team. The team also began arranging the meetings self-imposed after a few gatherings, which in turn resulted in the collaboration becoming even more smooth and effective. The durations of the meetings had been from a few hours to half a day, depending on the need. This relates to coordination theme also, as the meetings were arranged by the contractor in the beginning, but the team soon began to self-organize them. It had been a way of working which functioned well, and which the participants were very pleased with. The discussion about the benefits of frequent, regular meetings for design team members was something the focus-group had a consensus about.

### Early involvement of participants

The focus-group discussed a lot about early involvement of participants. The whole group thought that the example which the BIM specialist told about had a huge potential, but the costs, or the resources needed for them were further discussed:

- *"It could work like, that the team sees this suiting them, and includes it in the tender. We do a bid, we work like this and our space is here, is it ok for the owner? And it has this price."* (Main contractor)

They talked about the importance of even tendering the teams instead of individual disciplines. This was an idea in which the teams would offer their BIM process plans as part of the tender, and the best (a.k.a. Most effective and credible) plan, according to the project owner, would win.

**Level of Detail**

This topic seemed to be one of the most significant and easily handled of the challenges. According to the group, the decisions about the needed LoD in each discipline's model should be decided as early as possible in order to avoid unnecessary work. The main constructor's needs were forming the initial framework for this issue. The discussion about the subject extended further to the effects it can have in the collaboration itself:

- *"The early, detailed modeling done together will result in more rapid* commitment. *All participants engage to the decisions made, when they understand the reasons and consequences from also other disciplines' perspectives."* (Main constructor)

**Trust and willingness to cooperate**

Cooperation, activity shared for mutual benefit, means in this context, the willingness to model together instead of independently, and that all participants are willing to share their ideas and challenges during the process. The BIM specialist also thought that when the team scrutinizes the 3D-models together, e.g. the sense of making some decision about some structural choice will be clearer more easily. She also argued that if some solution would in some sense seem more economical, the rationale for choosing some other solution would come clear by scrutinizing the model together, and because of understanding others' motives. The BIM specialist also added that:

- *"And if we are in an IPD-model, everyone supposedly wants to get into a mutual solution."* (BIM Specialist)

The main constructor also suggested that one of the solutions MPA could bring to BIM challenges is that the designers will bring the unfinished work to be accepted, in a way, and thus certain issues can be identified earlier. There will not be situations where someone says "*why did you not say (about this) earlier*?"

- *" Choosing the net economical solution is a result of designers' increased mutual trust as well as the increased trust towards the owner and user, and the one who finances the project."*(Main Contractor)

In addition to trust, willingness to cooperate was discussed. The participants clearly expressed that cooperating will make remarkable difference compared to the *"normal way to work in the office alone on one's own model"* (Structural Engineer)

- *"The problems are caused by an individual who locally optimizes one's design…The benefits result from the whole group's collaboration in order to locally optimize the wanted part."* (Architect)

The architect and the rest of the group all understood the benefits from cooperating in design phase. This seemed to be one of the biggest differences when comparing the traditional and MPA projects. The group discussed a lot about working together from as early stages of the projects as possible.

- *"Team carries the risk together, knowing the schedule milestones and the end result, time spent and the costs involved, to decide in which phase to start doing this. The owner might force to collaborate more in the learning phase. And I think that they will pay clearly more for the preliminary design phase's designing in the future, as we will work more during it. In other words they will invest in the significant decision making points."* (Main contractor)

Collaboration, cooperation and trust among and between all key participants were in the core of the discussion throughout the workshop. In addition, coordination issues were in the focus of the group as the traditional construction methods are led by the main contractor and the sub-contractors of each discipline, and in MPAs the responsible one is decided among the group.

**Theme B: Coordination**

In this context, coordination means *"the act of making all the people involved in a plan or activity, work together in an organized way"* (Cambridge Dictionary).

Thus, the second theme, which was in the core of the discussion, was coordination of the team. In the group, there were opinions, which were about merely deciding on who coordinates.

- *"...The team decides the responsible individual, who coordinates. Sometimes it can be the main designer or designer lead design meeting, sometimes construction consultant lead, it just has to be decided."* (BIM Specialist)

Some examples, which relate to Theme A – Collaboration, were presented by the BIM Specialist as well as the structural engineer. They were discussing about the timing of modeling. This referred to deciding which parts or spaces were prioritized according to the needs on the site. According to the BIM specialist the self-reliant AEC designer might start from the upper floors' sealing, while the structural engineer is designing the bottom floor's load-bearing structures. She proposed that in order to avoid these risky ways to proceed, the team should decide the modeling order in advance, and control the plan in their weekly meetings following the instructions they get from the main contractor and/or BIM Specialist. The fact that the owner is part of the team brought some ideas related to the owner as well:

- "*It* (The design phase) *should be scheduled, in order for the owner to understand that the whole is under control. It will result as the implementation planning timetable, which will bind everything together. It would probably help Last Planner® System when planning and checking the deadlines."* (Main contractor)

In order to achieve timely design and construction the Last Planner® System was proposed several times during the three day workshop. The tool is already tested in some projects within the Model Nova research project.

**Theme C: Technical issues**

This theme includes the most technical issues which turned up during the workshop. The discussion went on a very detailed level from time to time, and it seems that the technical issues are very common. BIM Specialist tried to avoid going on this area as for her opinion, these are not exactly MPA related concerns. Thus, and because the challenges were not thoroughly discussed as far as it comes to getting enough data from the subject during the workshop, only few of them are presented here. These issues are related to collaboration and coordination resulting from MPA.

- *"Information about the quantities, checking the models, and the trustworthy of all of the participants' models, is first and foremost responsibility of each participant, but the whole group should check them after that."* (Structural engineer)

The checking was discussed in the earlier parts. The main contractor, or some other mutually decided person, could coordinate the process in order to the team to produce the wanted outcome. The checking out the models should be planned in advance, and the use of the models should also be explicitly instructed in the beginning of the project.

- *" For what purpose each model will be used during the life-cycle of the project, should be made very clear to each designer in very early phase of the project. That would result in less unnecessary work with their models."* (BIM specialist)

One way to cope with these challenges is to enhance coordination as well as the frequency of meetings for all members of the design team, not to forget any other stakeholders which the subject in question is concerned. This would result as a byproduct from MPA, as discussed earlier.

- *"The problem is that, even if some quantities are correct in the model, after which someone does a door listing, and someone else makes a document of it, the quantity does not print correctly."* (The architect)
- *"They should get more time to do it* (the model) *more meticulously. We see that the owner wants to get the quantities for communicating the proceeding of the project in the future. And then it is, in this kind of projects, of utmost importance to get the quantities correct in the procurement packages."* (Main contractor)

Also for this, literature suggests MPA, or IPD to be exact. When all disciplines discuss the details together, it results in minimizing the need for documentation for informing other disciplines about changes made etc.

**Theme D: Contractual Interests**

Contractual interests per se, were not in the core of the workshop but there was a conversation about some aspects. There were conversations about the minimum requirements for the model, and about responsibilities, which reflect to the shared risks and rewards. Main constructor argued that the minimum requirements will have to be written in the contract. That the requirement de-briefing, or the project-plan defines the requirements for each model.

- *"It's a bit like the target price – procedure; If You'll rise the target-price, then everyone will benefit from it. It is the rule of the game there."* (Main Contractor)

The biggest issue about contracting was about sharing the rewards and risks during the project. First, the participants were speculating with "who actually is responsible for the mistakes in the model?"

- *"In my opinion, if there is an incorrect raster which causes false quantities to the list which in turn causes additional costs to construction, the architect isn't solely* *responsible for it because of this contractual mechanism about sharing the risks and rewards."* (Construction Consultant)

Then, to clarify the opinion, the BIM Specialist gave also her comment:

- *Maybe I would say that, everyone is responsible for one's own model's correctness, and the one that takes quantities out of the model, with whatever technique, is responsible in a way for how to take them, and what is needed from which designer. But information-wise, the designer is the only one who could be responsible for making the mistakes into the model."* (BIM specialist)

The conversation gave a good idea about how the subject isn't very familiar among the participants, which is why the group decided for the subject to be dealt with within an assigned group after the Alpha workshop.

**Theme E: BIM Competence**

- *"It doesn't pay to take weak links to the team."* (Construction Consultant)

Competence in using and benefiting from utilizing BIM was also one of the topics which cannot be forgotten as it is the rationale for using BIM in the process in the first place. The discussion included issues related to the competence of both, designers and the users of the designs, especially on the site. The quantity related issues presented in Theme C – Technical Issues are related to designers' competence.

**Designers' competence**

BIM Specialist communicated how they prepare themselves for the designer competence issue:

- *" Well, we scrutinize the models. In the beginning of the project we instruct the architects to make the model according to our needs. After they are ready, we check it several times. And we also show how to reasonably easily check the model with their-own tools. Concerning the relevant parts, nothing irrelevant."* (BIM specialist)
- *"If the mistake is due to the incompetence of the modeler, the finger is obviously pointing in that direction."* (Construction Counselor)

The construction counselor also referred to the Finnish Building Information Modeling Guidelines in his other comment about stakeholders' competence:

- *”In COBIM-Guidelines it says, that the main designer has to make sure that all disciplines have adequate BIM competence. It is incomprehensive, as the constructor selects the team. That the main designer should have a possibility to reassure the competence of the rest of the team beforehand. “*

Thus, it seems that in case the constructor selects the team, the guidelines do not apply. For this challenge as well, MPA or tendering the whole team at the same time is proposed for the solution.

**Competence of the Users of the Models**

The whole group was obviously unanimous about the field workers’ need for the capability to utilize the models in their work. Unless they have the skills to read the models on site, the whole modeling would be pointless. In case of MPA, the owner is part of the team and thus taking part in the team meetings, so he/she will learn the needed skills to understand, or read the model during the process.

The solutions found in the empirical data is presented and discussed further in Part IV (Findings), and finally the theoretical and managerial implications, as well as the need for future research are presented in Part V.

# IV FINDINGS

In this part, in chapter 8 (BIM related challenges and the solutions), the findings are validated or invalidated testing the data with the initial constructed theoretical framework (in chapter 6, table 2). The findings will then be presented and categorized based on the initial theoretical framework, after which the analyzed empirical data are compared with, and finally integrated to the initial constructed theoretical framework in order to answer the second research question of this study (What kind of multi-party-agreement related solutions for BIM related challenges might there be for the future cases adopting BIM?). The results of this thesis are presented in form of the enhanced constructed framework (table 4).

## 8 BIM related challenges And the Solutions

For readability reasons, the challenges are presented in the same order as they were in the initial constructed theoretical framework. Below each challenge there are also the proposed solutions for the challenges, complemented with the findings from the empirical data. In the framework, the solutions from empirical data are presented in the “Empirical Solution”-row.

1. Collaboration

The transparency regarding the goals to be achieved, the rules and responsibilities of each member, the clarity of the status of the development as it evolves, and the level of commitment of each team member are fundamental for a supportive environment. Theory suggests that the Multi-party Agreements such as IPD, PP and PA increase collaboration as all parties are treated equally in the context of partnering, and thus they are encouraged to share information and knowledge. The empirical findings propose also that early involvement of participants and frequent designer meetings with owner, and site managers, when needed, could solve the issues related to collaboration. Tight collaboration between participants, including the owner, will increase understanding of each other’s work and also the impacts of occurring changes.

Designers are dealing with the uncertainty and complexity inherent to building projects and by managing commitments they achieve a stable and smooth process, a project running with less variability. Changes occur because of several reasons like technological development, changing space needs, and limitations in constructability. Design changes occur often even when the customer is aware of the consequences. The one who is financing the project is responsible for compensating for the rework. Nevertheless, well-defined processes for potential, predictable changes were proposed in both literature, and in the empirical data.

2. Coordination

The question is without doubt among the most critical ones when it comes to BIM related challenges. BIM implementation success depends on how well the workflow and information flow is streamlined. The subject was in discussion also in the focus-group meeting. The focus-group discussed the suitable solutions for different coordination challenges, and the MPA's and Lean methods such as Last Planner® System (LPS, presented in detail in chapter 5.2.5) were proposed.

LPS is perceived important in dealing with uncertainty in the course of design development, and it is proved to be functioning method for accomplishing schedule accuracy. Thus, the MPA-team was suggested to meet frequently, once a week for instance, in order to keep up the same pace with each other and to check the needed information, and needs in general, as soon as they come about. Thus, the schedule will stay as accurate as possible, when the team plans and adjusts the plan every week according to the outcomes of the current or previous week, depending on the weekday on which the meeting is arranged.

The organizing itself was unanimously thought to be decided among the key participants, and the timing for this was suggested to be as early as possible in the process. The key issues should be discussed in the team, and the decision making points were suggested to be decided in advance. Nevertheless, the structural engineer argued that the scheduling should be done forward instead of backwards from some deadline, which according to his pragmatic experience causes usually time-pressure and delays. One suggestion which also came up was that when choosing the MPA-teams already in the bidding phase through choosing the team with best process, they would have their modeling process already planned.

3. Contractual interests

These partnering agreements, such as IPD and alliance contracts, have been used only in a few cases in Finnish construction industry, and mainly in infrastructure projects, thus the barrier for implementing this kind of contractual relationship appears to be high. The question about contractual interests came up in the second day session in the focus-group workshop. The atmosphere among the construction managers seemed to be very receptive, as soon as the contracting research has proceed enough as far as the risk management is concerned.

The rationale in which the profits should be distributed, were not clear either, because the amount of each stakeholders' work is vague, as it has not been accurately measured within neither the previous projects, nor even in the individual companies. Nevertheless, the result was that the question shall be answered later by a separate group, which was to be formed shortly after the focus-group meeting. The group has now been formed, but the results will not be available during the research process of this thesis.

4. Data Interoperability

The major opportunity for improving the design and construction of facilities lies at the interfaces between disciplines. Thus, data should be available for all stakeholders in real-time, which will keep data accurate and processes between different disciplines smooth. There is also certain level of accuracy needed from each discipline by the contractor and site workers. For this, the empirical findings suggest that the issues are to be discussed already early in the project within the key participants including the designers as well as the constructor and site managers. It is all about making the decisions about which softwares to use, and who is responsible about which design phases and tasks. An architect for example would not need to divide the model into blocks, stratifying it, or take the lists of materials or quantities from the model. That can be done by the main constructor who can also revise the models in decided points during the design phases. Obviously the designers' responsibility about the modeling itself still remains the same. The accuracy of the modeling is something the design team has to decide in very early phase of the project, and communicate with each other during the design process if the needs change.

Conflict identification didn't get as much attention in the focus group meeting as I had assumed. There seemed to be certain procedures by which the clash detections are done. The most common way was that the main constructor does the detection as part of the model controls during the project's different phases. Combining the models was generally in the end done by an expert within the main constructing company by COBIM rules and standards (See the definition in definitions, p. IV).

5. BIM Competence

The empirical research data showed that the solution to this challenge about lack of BIM using competence is to choose the team members and sub-contractors according to their BIM-using skills. Also educating them in the beginning of the project was mentioned. Educating the group would obviously increase mutual understanding about the requirements for the models as well as decrease duplicate information entries or information loss during the current project. Sub-contractors should be taken into the meetings as well in order to clarify the modeling needs for their part. The lack of readiness to use BIM should in other words be solved by choosing suitable partners into the project. Thus, if modeling should be needed from the sub-contractor, incapable sub-contractors are not to be chosen. Financing the needed resources should also be part of the agreement, as the modeling efforts are vital for the team. If the benefits of modeling would affect the profits sufficiently, then it would be rational to finance the needed BIM tools for the participants already in the beginning of the project.

People involved in the project, should be aware of the design process and its constraints. Theory implies that the clear definition of customers' values and expectations is the starting-point, and open budgets will increase knowledge about the consequences of certain changes. The 3D models used for design coordination, and the meetings to share performance indicators were also suggested.

The above mentioned challenges related to BIM, and the recommended solutions which MPAs could offer for them, are presented in the following framework (Table 4, below). The new findings related to the challenges are in the row "BIM related challenge (Empirical data" and findings related to the solutions are in row "Empirical Solution". The novel findings are bolded.

**Table 4. Challenges and the Solutions - The ENHANCED Constructed Framework**

| | | | | | |
|---|---|---|---|---|---|
| **BIM related challenge (Literature)** | **1. Collaboration:** The most frequently identified issue is related to collaboration (including communications, and document management). (Shen et al. 2008 and Mäki et al., 2012) One issue is about collaborating in order to understand the impact of the design changes in others' work, and in the overall budget. (Kemmer et al. 2011) | **2. Coordination:** The issues were firstly about how to organize the project team, and structure the coordination processes to best utilize the VDC (virtual design and construction) tools. (Khanzode et al. 2008 and 2012) And secondly, how to create the guidelines for the most efficient use of BIM / VDC tools for the process such as conflict identification. (Khanzode et al. 2012, Mäki et al., 2012) | **3. Contractual interests:** The challenges were mainly issues such as how to align the contractual interests of the coordination team to meet the overall project schedule? (Khanzode et al. 2012) And, how to allocate profits between the team members? | **4. Data interoperability:** (Bernstein and Pittman, 2005), This challenge includes the need to investigate BIM level of detail requirements of various stakeholders for different design and construction disciplines. (F. Leite et al., 2011) | **5. BIM Competence:** Major concern is the lack of BIM know-how (Lavikka et al., 2012 and Mäki et al. 2012) and sub-contractors' lack of readiness to use BIM (Linderoth, 2010). |
| **BIM related challenge (Empirical data)** | **Owner's participation** is one of the issues, as the most significant changes are resulting from owner's decisions. (All focus group participants) | **Team members' different paces in designing** was also one of the major concerns. (All focus group participants) | According to empirical data, also: **how will the designers get their earned pay-offs for the early design phases**, as the work distribution during the BIM process is emphasizing the beginning of the project more than in the traditional design process? (Architect) | **Which are the means to ensure the compatibility** of designers' models? (Architect) | Are there any **best practices** in order **to ensure the participants' BIM competence?** (Answered by the BIM expert) |
| **Solution (Literature)** | Multi-party Agreements such as IPD, PP and PA include the guidelines in which all participants are engaged. (Lahdenpera, 2012) Management protocol should be set: The transparency regarding the goals to be achieved, the rules and responsibilities of each member, the clarity of the status of the development as it evolves and the level of commitment of each team member are fundamental for a supportive environment. (Kemmer et al. 2011) | MPA's and Lean methods as LPS uses Lean methods to improve project control. (Forbes and Ahmed, 2011. P. 86) MPAs include the guidelines in which all participants are engaged, and the implementation of Last Planner System (LPS), on the other hand, is perceived important in dealing with uncertainty in the course of design development (Kemmer et al, 2011) as BIM implementation success depends on how well the workflow and information flow is streamlined. (Smith and Tardif, 2009. P. 106) Modeling the complex requirements, and transforming the complex requirements model into system architecture, was also suggested. (Arayici et al, 2007) | The generation of a considerable amount of extra information at an early stage must have contractual support. (Kemmer et al. 2011) If project events justify changes to targets and profit, the need for any construction contingency is reduced. As a result, construction contingencies can be smaller in a well-drafted IPD agreement. (H.W.Ashcraft, Jr, 2010) In addition to MPAs, Kemmer et al. (2011) suggests Last Planner System for aligning the contractual interests. | The major opportunity for improving the design and construction of facilities lies at the interfaces between disciplines (Fisher and Kuntz, 2004). Thus, the solutions proposed include well-defined transactional construction process models (Bernstein and Pittman, 2005), joint decision making (Forbes and Ahmed, 2011) and adopting open standards when possible (Smith and Tardif, 2009. P. 97). | Multi-party Agreements such as IPD, PP and PA. (Lahdenpera, 2012) Early involvement of participants, joint decision making (Forbes and Ahmed, 2011), Educating the team through interactive BIM reviews is essential for demonstrating the field workers the work flow and building order.Thus, also the field workers need the ability to read the model. This is achieved by educating the crew. (Eastman et al., 2008. P. 102-103) New roles such as BIM consultant, construction consultant, or life-cycle consultant might also be needed, as "BIM implementation success depends on how well the workflow and information flow is streamlined." (Smith and Tardif, 2009. P. 106) |
| **Empirical solution (The Findings)** | 1. **The (main-) contractor or construction consultant arranges guidance for the team members in the beginning of the project, and**<br>2. **provides location(s) for the team for meeting frequently to collaborate efficiently throughout the process.**<br>3. Openness in sharing knowledge about each others working habits, budgets and needs within the group is also considered important. In addition,<br>4. the owner is considered to be a significant participant of the team, as the whole project is conducted in order to construct the building according to his wishes and | 1. **Designers for the project are tendering as teams. The team with most suitable process plan wins.**<br>2. **Constructor should also arrange weekly meetings for the design team so that they can solve any emerging challenges in the modeling as soon as they occur.**<br>3. **Contractor should also validate the models before integration of the models and**<br>4. **makes sure that the team is aware of the requirements and guidelines for each model in the very beginning of modeling phase.**<br>5. Also LPS was suggested, as the weekly meetings or even co-location is part of the system. | This part is not thoroughly covered in the empirical data as contracting was left out of workshop's agenda. The group thought that a special workshop should be arranged in the near future for discussing the subject. Nevertheless, there was one issue, which was answered by the group. According to the data, **the owner of the project would appreciate the designers work in the early phases of the project when the pay-off for the modeling work is included in the MPA contract, and when the owner is part of the team right from the beginning of the process.** This subject remains as a need for future research. | 1. **It is all about making the decisions about which softwares to use, and who is responsible about which design phases and tasks.**<br>2. Constructor makes the requirements for the different models clear in early stage of process, and makes sure that the team is equipped according to the needs. The end result for knowing the requirements for each model, is that only the needed work will be done with the right tools, and thus unnecessary work | 1. All participants need the skills to use the models according to the scope aligned for it. Thus, **the constructers should arrange instruction for the team in the beginning of the process in order for them to be able to meet the project's needs and requirements.**<br>2. **Constructor should also arrange weekly meetings for the design team so that they can solve any emerging challenges in the modeling as soon as they occur.** |

# V DISCUSSION

This is the final and concluding part of this Master's Thesis. The part consists of three chapters. Firstly, the theoretical and managerial implications of this study will be discussed (Chapter 9, Theoretical and Managerial Implications), second the findings are generalized and integrated into more simple and illustrative theoretical model representing the conclusions of this thesis (Chapter 10, Figure 6), then the validity and reliability of this study will be evaluated, and the need for future research will be proposed (Chapter 11, Validity, Reliability, and Future Research).

## 9 Theoretical and Managerial Implications

The objective of this study was to construct an enhanced framework which will answer the research questions of this thesis. The questions were

*1. What are the main challenges related to construction process when utilizing BIM?*

*2. What kind of multi-party-agreement related solutions for BIM related challenges are there for the future cases adopting BIM?*

The enhanced framework is based on the BIM related challenges and the respective solutions found in literature, which are complimented with the gathered empirical data about the challenges, as well as the solutions to the found challenges. In this chapter the implications of the findings are discussed as follows.

### 9.1 Theoretical Implications

The theoretical objective was to give new theoretical contribution to the field, by validating or invalidating the challenges and solutions found in the literature, by comparing them in the enhanced constructed framework with the empirical data. The Implications are presented by the five themes of BIM related challenges presented in the constructed frameworks, namely collaboration, coordination, contractual interests, data interoperability, and BIM competence. The findings both reinforced the previous knowledge and complemented it. In all themes more detailed challenges were distinguished, and the empirical data validated and complemented the solutions found in literature. One of the solutions, namely the ones under theme 3 - Contractual Interests, was harder to validate, as the subject was left outside the focus group's agenda. Still, some discussion about the subject occurred.

#### 9.1.1 Collaboration

According to Shen et al. (2008) and Mäki et al. (2012), the most frequently identified issue is related to collaboration (including communications, and document management). One of the issues was understanding the impact of the design changes in others' work, and in the overall budget (Kemmer et al. 2011). The empirical data *complemented* this theme of challenge with the lack of owner's participation, which resulted from distinguishing the fact that the most significant changes are resulting from owner's decisions.

Empirical data *also complemented* the set of solutions by adding that the (main-) contractor or construction consultant should arrange guidance for the team members (or key participants) already in the beginning of the project, and provide location(s) for the team to meet frequently to collaborate efficiently throughout the process.

Openness in sharing knowledge among the team members about each-others working habits, budgets and needs, as well as transparency regarding the goals to be achieved, was also considered important both in literature and empirical data. Empirical data showed that constructor should make sure that the team is aware of the requirements and guidelines for each model already in the very beginning of modeling phase**.** The trust between the team members, in order to be able to show and discuss also incomplete models, was also considered important for accomplishing successive collaboration.

### 9.1.2 Coordination

The issues were firstly about how to organize the project team, and structure the coordination processes to best utilize the VDC (virtual design and construction) tools. (Khanzode et al. 2008 and 2012) And secondly, how to create the guidelines for the most efficient use of BIM tools for the process such as conflict identification. (Khanzode et al. 2012, Mäki et al., 2012) This list of challenges was complemented according to the empirical findings with "team's different paces in designing". The data offered also the solution for the challenge. The team was to meet frequently, once a week for instance, in order to keep up the same pace with each other, and to check the needed information and needs in general as soon as they come about. Thus, the schedule should remain as accurate as possible, as the team plans and adjusts the plan every week according to the outcomes of the current (or previous) week.

BIM implementation success itself depends on how well the workflow and information flow is optimized. (Smith and Tardif, 2009. P. 106) As Forbes and Ahmed (2011, P. 86) have argued, MPA's and LPS uses Lean methods to improve project control. MPAs include the guidelines in which all participants are engaged, and the implementation of LPS is perceived important in dealing with uncertainty in design development (Kemmer et al, 2011) It is critical to project control's effective deployment as it uses process-driven approaches for project control, which in turn improves workflow reliability and enables planners to better match the supply of resources to site demand, and thus results in accomplishment of higher percentage of planned tasks. Kemmer et al. (2011) suggested that the generation of a considerable amount of extra information at an early stage must have contractual support.

Theory also suggested, that modeling complex requirements, and transforming the complex requirements model into system architecture, is one way to achieve functioning collaboration. (Arayici et al, 2007) This was also *validated* by empirical data, but the terminology was different. In Finland, BIM has its own guidelines, which are called COBIM. And the guidelines could be considered to be the complex requirements model. Although, COBIM did get some criticism within the focus group about some requirements for the main designer, "who should make sure that all of the team members are sufficiently competent in using BIM". This was considered impossible under circumstances where the designer team is chosen by the owner of the project already in the tendering phase. Empirical data *complemented also*, that the contractor should validate, or check the models before integration of the models in order to accomplish as flawless models and IFC's as possible, according to the information requirements given to the designers in the beginning of the project.

### 9.1.3 Contractual Interests

The challenges were mainly issues such as how to align the contractual interests of the coordination team to meet the overall project schedule? (Khanzode et al. 2012) And, how to allocate profits among the team members? The empirical data *complemented* the set of challenges with: "How will the designers get their earned pay-offs for the early design phases, as the work distribution during the BIM process is emphasizing the beginning of the project more than in the regular design process?"

Theory (Kemmer et al. 2011) also suggested that generation of a considerable amount of extra information at an early stage must have contractual support, and the solutions were found from multi-party agreements such as IPD, PP and PA, which include the guidelines in which all participants are engaged. (Lahdenpera, 2012) According to the empirical data, the solution is that the owner of the project would appreciate the designers work in the early phases of the project when the pay-off for the modeling work is included in the MPA contract, and when the owner is part of the team right from the beginning of the process. Ashcraft, Jr, (2010) argued also that if project events justify changes to targets and profit, the need for any construction contingency is reduced. Ergo, construction contingencies can be smaller in a well-drafted IPD agreement. In addition to MPAs, Kemmer et al. (2011) suggested Last Planner System for aligning the contractual interests as it increases the amount of interaction and coordination among the key participants. In order to get all participants engaged to LPS in the first place, it should also be written in the Multi-Party Agreement.

### 9.1.4 Data Interoperability

This challenge includes the need to investigate BIM level of detail requirements of various stakeholders for different design and construction disciplines. (F. Leite et al., 2011) This theory was also *validated* according to the empirical data: When the designers are all instructed in the early phases of the process, for which softwares to use, in which LoD they should model, and with which tools, their data interoperability issues will be solved. The end result for knowing the requirements for each model, is that only the needed work will be done with the right tools, and thus unnecessary work will be minimized.

In addition, the solutions proposed include joint decision making (Forbes and Ahmed, 2011) and adopting open standards when possible (Smith and Tardif, 2009. P. 97). Empirical studies did not show that open standards should be used, as the technical issues were not in the core of the discussion. Actually, the BIM expert did not have any major difficulties in solving the challenges and did not want to use any time for discussing them. Some designers, on the other hand, were struggling with some technical issues (e.g. taking lists from some space's materials) but BIM expert had means to cope with them as well. The solution seemed to be the instructing all designers in the very beginning of the project about the requirements for each model, and about the tasks for each discipline. The models were integrated, and the needed lists were produced by the BIM expert after scrutinizing the models for errors.

### 9.1.5 BIM Competence

According to the literature, one of major concerns is also the lack of BIM know-how (Lavikka et al., 2012 and Mäki et al. 2012) and sub-contractors' lack of readiness to use BIM (Linderoth, 2010). Empirical data *validated* these requirements and the related challenges, clarifying that all participants need the skills to use the models according to the scope aligned for them. As already mentioned, the constructers should arrange instruction for the team in order for them to meet the project needs and requirements. The team can also be chosen already in the tendering phase according their readiness to model. That will assure that they have the needed competence.

Theory suggested multi-party agreements for solutions (Lahdenpera, 2012), as they usually involve early involvement of participants and joint decision making (Forbes and Ahmed, 2011), which in turn increase knowledge sharing and thus, also learning. Educating the team through interactive BIM reviews was also suggested to be essential for demonstrating the field workers the work flow and building order. (Eastman et al., 2008. P. 102-103) Empirical studies *validated* the need for site workers to be able to use the models. Otherwise modeling was considered to be unnecessary in the first place.

Both, empirical data and literature showed that new roles such as BIM consultant, construction consultant, or life-cycle consultant might be needed in the future, as BIM implementation success depends on how well the workflow and information flow is optimized. (Smith and Tardif, 2009. P. 106) And, the one streamlining the information flow, could be one of the above mentioned consultants if the other participants are not competent or do not have enough time to coordinate the actions of team.

## 9.2 Managerial Implications

In this sub-chapter, the purpose is to present how the findings of this study affect people's work in the actual future construction projects implementing BIM. In fact, most of the suggestions apply also in projects conducted using the traditional methods, as collaborative work with decent coordination, and knowing each-other's responsibilities, working schedule and working habits, create trust among the participants, thus effecting positively in the work aiming towards a functioning whole. The managerial implications are also presented by the themes of the constructed frameworks, and they include the author's conclusions on the topics.

### 9.2.1 Collaboration

According to the findings of this study, collaboration is among the most interesting issues related to projects implementing BIM.

**Solutions:**

a) *The constructor should provide transparency regarding the goals to be achieved* in order to make sure that the team is aware of the requirements and guidelines for each model in the very beginning of modeling phase**.** The built team spirit affects the team as they feel that they have a mutual goal to achieve.

b) The designer teams need *the contractor to provide location(s) for the team to meet frequently* in order to collaborate efficiently throughout the process. This can be enhanced by implementing LPS, which will bring accuracy to the coordination process related to the weekly goals.

c) *The generation of a considerable amount of extra information at an early stage should be taken into account already in the contract*. Thus, the suggested solutions include Multi Party Agreements as the idea in them is *to allocate the profits between the participants according to their efforts*. To complement the agreement, LPS's byproduct is the documentation of each discipline's, and individual's weekly goals and achievements.

d) *Tendering the whole teams instead of individual designers*. The team creates a process model about their modeling work, in order to achieve effective process for the collaboration. An effective collaboration between the key participants will then begin already in the very beginning of the project. It will also increase trust and openness among the group, as they will gain more knowledge about each-other's working habits, and they will learn earlier about each-other's needs concerning the modeling. This in turn decreases the need for iterations and rework, and thus budget increase, during the process. Same applies when trying to understand the impact of the design changes in others' work, and in the overall budget.

e) Finally, *the owner should be a key participant of the team right from the beginning of the project*, and take part to the weekly meetings with the designers, and also site managers, whenever their attendance is needed. After all, the most significant changes, affecting the amount of possible rework, and thus the budget, are resulting from owner's decisions.

### 9.2.2 Coordination

Coordination was also one of the major challenges according to the findings. In order to collaborate effectively, coordination is vital.

**Solutions:**

a) The issues concerning coordination were firstly about *how to organize the project team* itself. As the findings showed, the team of designers could be tendered instead of tendering the individual designers separately. This would result, depending on the requirements of the bid, in a well-planned process of the team, increasing the possibility of succeeding in the realization of the plan. This applies also to the challenge of structuring the coordination process to best utilize BIM tools.
b) According to the findings, one of the greatest issues related to coordination, was the *team's different paces in designing*. The team should decide the pace among them, in addition to informing each other about the current situation in the weekly meetings, in order to keep up the same pace with each other, and to check the needed information and other needs as soon as they occur.
c) Challenges of *creating the guidelines for the most efficient use of BIM tools* for the processes such as conflict identification, can be solved in addition to what is already suggested in section a, by creating written guidelines for BIM, in Finland the national guidelines are called COBIM. Nevertheless, the rules have to be set from project to project, as the teams often utilize different tools, and they have different working habits.
d) *The contractor should validate, or check the models before the integration of the models* during the process, in order to accomplish as flawless models and IFC's as possible, and to make sure that the team is still proceeding in harmony. This task can also be assigned for some other mutually decided responsible than the contractor.

9.2.3 Contractual Interests

This challenge was not solved according to the findings of this study. Nonetheless, the contracts are always vague until the stakeholders have decided on the details.

a) The questions rising from MPAs are first and foremost about the *allocation of risks and rewards among the key participants*. They include the **changed workloads required from individual disciplines, and the division of work during the process** compared to the traditional construction methods.
b) *The contracts should also include if LPS will be implemented in the project, or not*, and how will it affect the workload division between normal design work, and the required meetings related to LPS.
c) Empirical data showed that designers often think that *the meetings are consuming time from the design work itself*, but in reality, the frequent meetings make sure that all

participants are in line with their work, and they can share their problems and needs as soon as they emerge, which will reduce rework and iterations, and thus **decrease the amount of the actual design work instead of adding workload**.

### 9.2.4 Data Interoperability

The empirical research did not give sufficient amount of data about this subject as softwares and e.g. so called “cloud servers”, which makes real time and even simultaneous model updating possible, were excluded from the agenda of the focus group meeting. Nevertheless, I will provide some insights to the subject as follows.

**Solutions:**

Findings showed that one of the related challenges was about the need to investigate *BIM level of detail (LoD) requirements* of various stakeholders for different design and construction disciplines. (F. Leite et al., 2011) This was actually *validated* also according to the empirical data: When the designers are all instructed in the early phases of the process, for who is responsible for which tasks, for which softwares to use, in which LoD they should model, their data interoperability issues will be solved. The end result for knowing the requirements for each model, is that only the needed work will be done with the right tools, and thus unnecessary work (e.g. rework and the amount of iteration rounds) will be minimized.

### 9.2.5 BIM Competence

The generational issues can be positively impacted by using BIM (Figure 6, below). This has major impacts on how know-how will increase among the experts of the field. (Lloyd-Walker and Walker, 2011) Generation Y will get proper BIM education already during their studies, but the mutual understanding and variations in BIM competence between individuals within projects are still currently substantial. When tendering the whole teams, the team can be assumed to be formed in mutual understanding about all members’ strengths and weaknesses, in order to meet the pre-planned process, and schedule for it, even though some new skills are to be obtained by some disciplines during the process.

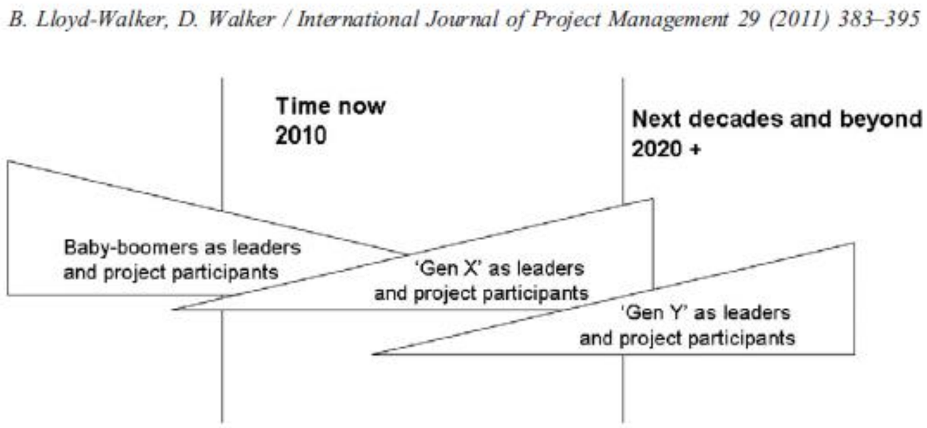


**Figure 6. Generational handover of leadership.**

## Solutions:

a) *Lack of BIM know-how*: All participants need the skills to use the models according to the scope aligned for them. In addition to the designers, the site workers have to have competence in using the models in their work. Thus, *the contractor should organize instruction for the project team members* in the beginning of the project. It will clarify the tasks and task allocation between the designers, as well as make sure that all designers have the needed skills in order to accomplish the wanted outcome. This can also be accomplished by choosing competent work force in the first place by tendering the individual designers and other participants, or teams, according to their competence.

b) *Sub-contractors' lack of readiness to use BIM*. It isn't self-evident that all smaller companies involved know how to utilize the models. They might also have insufficiently incentives and resources to invest in the needed equipment. *Sub-contractors can also be chosen based on their modeling skills*, or competence in using the models.

c) Findings also showed that *new roles such as BIM consultant, construction consultant, or life-cycle consultant might be needed* in the future, as the one streamlining the information flow, could be one of the above mentioned consultants. This can be same person as e.g. the contractor. The responsible should just be chosen among the participants.

**Suggestions in nutshell**: MPAs are suggested for solving also this challenge as they usually involve early involvement of participants and joint decision making as well as incentives to get the needed competence. LPS on the other hand will increase knowledge sharing, which inevitably increases also learning within the team.

# 10 Conclusions

The objective of this Master's Thesis was to find answers to the research questions (RQ), which are:

*1. The main challenges related to construction process when utilizing BIM?*

*2. What kind of multi-party-agreement related solutions for BIM related challenges there are for the future cases adopting BIM?*

This study was conducted using constructive research approach. First the initial theoretical framework was constructed according to the literature review by writing BIM related challenges in one row and the solutions found in literature, in the other. The initial constructed framework was then used for reflecting the findings of the empirical data. The data was gathered in a focus-group meeting by recording the sessions, and the recordings were transcribed only insofar as the parts were giving answers to the research questions of this thesis. The data was analyzed by relating the relevant comments from the focus group participants with the BIM related challenges, or solutions respectively, and the findings were used for constructing the enhanced framework (presented in chapter 8, table 4). The enhanced framework's purpose was to illustrate the results of this thesis in a generalized form.

## 10.1 RQ 1: The main challenges related to construction projects

The challenges found in literature were both technical and managerial. Technical challenges included data interoperability, and according to empirical data, also some of the challenges related to printing lists (e.g. material) from the different disciplines' models. This did not seem to be a problem according to the BIM expert, though. She does the lists herself after scrutinizing the ready models. She thought that the one who is responsible of a task should do the work. In this case she referred to being responsible for the order quantities, and thus checking the model, after which printing the needed lists her-self. In a way this obviously seems also to be a managerial challenge, as the coordination and division of tasks has to be managed in order to accomplish the results as presented. Other managerial challenges were also mainly to do with collaboration, coordination, and BIM competence.

Challenges which related to collaboration are commonly acknowledged. In literature the challenges are insufficient amount of decision making points, that includes also the lack of knowledge about *by whom, or when* some prominent decisions should be made, and insufficient decision making about the level of detail (LoD) among the disciplines. Lack of proper design coordination, relates to collaboration as well, as shown in the model about BIM related challenges and MPA related solutions (figure 7). The Collaboration is coordinated, in order to obtain the goals as planned.

Contractual interests, was the third theme of challenges, which emerged in both literature and the empirical data. Contracting includes national differences, as they are based on legal aspects, and liabilities. Contracts are also written tailor made from project to project, as construction projects are all unique. This challenge wasn't thoroughly examined in the empirical study, but was postponed to be considered in another occasion. The work continues within RYM PRE Model Nova research project.

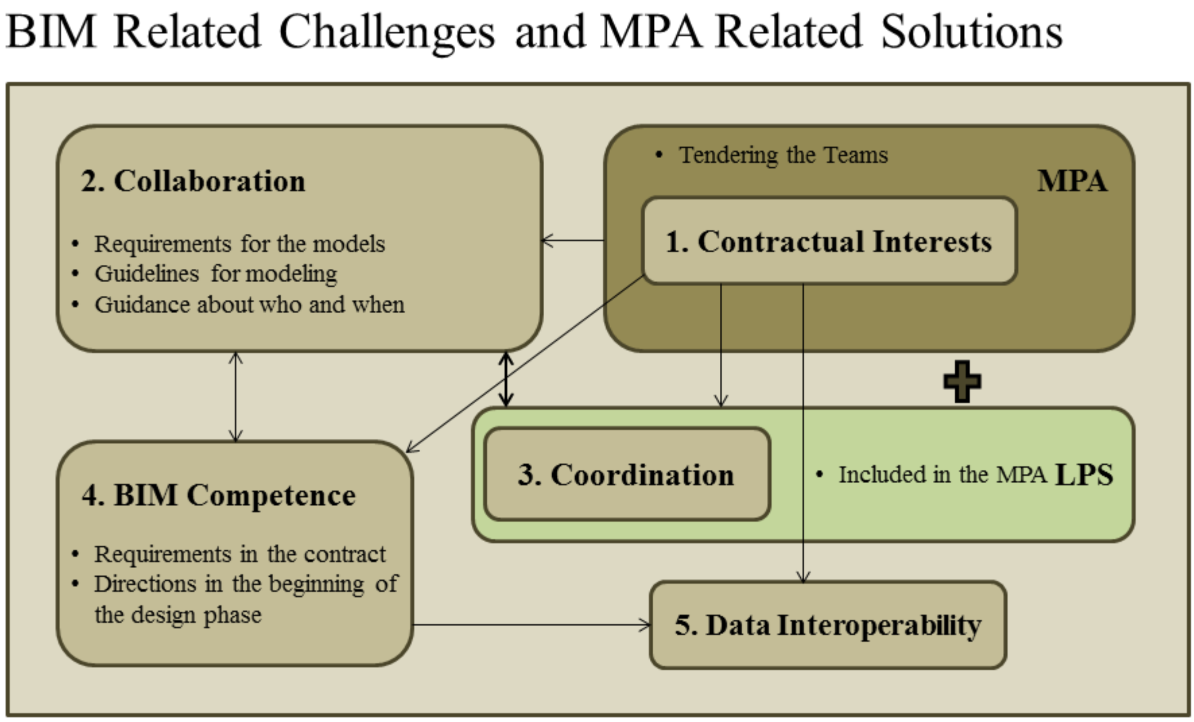


**Figure 7. Model about Conclusions - BIM Related Challenges and MPA Related Solutions.**

10.2 RQ 2: Multi-Party Agreement related solutions for BIM related challenges

The simplified model of the findings of this study (figure 7) shows the conclusions of this thesis. Multi-Party Agreement includes the mutually determined contractual interests (see 10.1), which in turn should include software and other requirements in order to avoid data interoperability issues during the process. Also BIM competence requirements should be included in the contract in order to make sure that the needed skills are available. MPA is designed in collaboration, and the collaborative team is obviously also defined in the agreement itself, which is also signed by the participants. The collaboration is based on the requirements for each model and discipline, and on the decisions about how to coordinate the collaboration. The coordination should be organized using work-flow management tools such as Last Planner® System. LPS should also be a prerequisite already in the MPA. In a list form, MPA related solutions include:

1. Early involvement of participants, and thus effective collaboration starting from the beginning of the project
2. The team can also be tendered in order to achieve best results, as far as collaboration and BIM competence within the team is concerned
3. Mutually defined contract, which includes who, what and when certain decisions are to be made, and how to allocate the profits and risks between the participants. Also the determining about the used coordination methods such as LPS should be considered in the contract
4. Because of the early involvement of participants, as well as tendering the teams instead of the individual participants, the possible data interoperability issues can be solved in advance, before they occur.

# 11 Validity, Reliability, and Future Research

## 11.1 Validity and Reliability of This Study

There are always threats to external validity if research is not done in laboratory conditions. Humans also engage with their world and make sense of it based on their historical and social perspective. Thus, qualitative researchers seek to understand the context or setting of the participants through visiting this context and gathering information personally. They also make an interpretation of what they find, an interpretation shaped by the researchers' own experiences and backgrounds. (Creswell, 1994. P. 10) These inducements need to be taken into account when giving recommendations of applicability. Validity in qualitative research refers to the reliability, consistency, predictability, dependability, stability, and accuracy of the data, which "thus can be defended when challenged". **(**Bashir et al., 2008) Every repetition of the same study should in other words lead to similar findings.

The credibility can be improved by prolonged engagement, persistent observation and triangulation (i.e. using multiple sources, methods, investigators and theories). The findings can also be peer debriefed to test the findings with disinterested peer or member checked where the results are discussed with different stakeholders and other researchers.

Of the above mentioned, the credibility of this study was obtained by triangulation, and peer debriefings. Peer debriefings were conducted by the two directors of this thesis as well as by the professor who also grades the study. The triangulation was obtained by constructing a framework about the challenges and solutions found in the literature, and testing the empirical data gathered in the focus group meeting with the framework. Finally the validated or invalidated findings were gathered into an enhanced framework, after which the theoretical and managerial implications for future projects utilizing BIM were discussed.

The results can be obtained in similar environment by conducting a focus-group meeting for teams that have been working in projects utilizing BIM. The teams should have all the relevant disciplines represented in order to have fertile conversation on the BIM process.

## 11.2 Need for Future Research

Part of the solutions for the found challenges, had been confirmed in real cases, and part of them were novel ideas from the participants of the focus group. In both cases, additional research will be needed in order to confirm the universality of the proposed solutions. In spite of the fact that the implementation of Multi Party Agreements, and especially the contracts concerning the alliance, have been successful in the majority of the cases studied in the U.S. (Kemmer et al. 2011, Mauck et al. 2009, etc.), the contractual part will remain a subject for future research, when it comes to Finnish projects conducted using MPA.

Another work-flow management tool which is currently rarely implemented in Finland is LPS. Even though LPS have recently been tested in design phase of a construction project, it should be tested in several other construction cases in order to validate the universality of the findings. LPS was proposed by the focus group participants based on only its theoretically interesting and credible impression as they had no experience in implementing LPS in their previous projects.

In addition to the above mentioned, the empirical research rose several novel decision making processes to be conducted in the project specifically tailored MPAs. The new process models have a working title of knot-working, which is to be tested in the forthcoming cases within RYM PRE Model Nova research project, in which also tailored MPAs are to be implemented. These case studies offer us valuable information about the current development of Finnish construction industry, and gives an over view on future potential in MPAs when utilizing BIM.

Finally, one of the five themes of the findings, theme 3 - data interoperability, needs further research as it wasn't sufficiently discussed in the focus group workshop in order to unquestionably validate the theories about the subject found in the literature.

## 11.3 Proposed Research questions

- What are the main challenges related to projects using Multi-Party Agreements (in Finland)?
- Who in fact should form an ideal Multi-Party team? – Cross Case Analysis
- What differences does BIM bring about to Multi-Party Agreements Compared to Traditional Construction Projects?
- Ideal Process Model For a Construction Project implementing Last Planner System
- Last Planner System in Construction Phase – Case Studies in Finland

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