Aalto University
School of Science and Technology
Faculty of Engineering and Architecture
Structural Engineering and Building Technology

Agnes Knopp-Trendafilova

LINK BETWEEN A STRUCTURAL BUILDING INFORMATION MODEL AND CLASSIFICATION SYSTEMS IN CONSTRUCTION

Master's thesis submitted for the grading as part of the degree of Master of Science Espoo 18.05.2010.

Supervisor:	**Professor Juhani Kiiras**
Instructor:	**Jukka Suomi, M.Sc.**

AALTO UNIVERSITY SCHOOL OF SCIENCE AND TECHNOLOGY **Faculty of Engineering and Architecture**			**ABSTRACT OF THE MASTER'S THESIS**
Author:	Agnes Knopp-Trendafilova		
Thesis:	Link between a structural model of buildings and classification systems in construction		
Date:	18.05.2010	**Number of pages:**	8 + 86
Professorship:	Structural Engineering and Building Technology	**Code:**	T2060
Supervisor:	Professor Juhani Kiiras, Aalto University School of Science and Technology		
Instructor:	Jukka Suomi, M Sc., Tekla Corporation		
Key Words:	Structural model, Classification system, 4D, Cost estimation		

The objective of this study is to identify possible links between generic construction classification systems and the structural design model. The key processes of different players of the construction industry are examined. These processes indicate - necessary links between the structural model and the classification systems. Additionally, Finnish, USA-based and international classification systems are compared. Building Information Modeling solutions used in Finland and the USA are studied and compared in the perspective of Tekla Structures, a model-based software product.

Construction project forms and process diagrams in Finland and in the USA are presented in the theory part and the description of the built environment by classification systems is implemented.

Building 80, 90 and 2000 from Finland, the MasterFormat 2004 from the USA and Canada, as well as the internationally developed OmniClass system are compared. The main difference between MasterFormat 2004 and Building 2000 is that the American system is based on work results, whereas the Finnish one is based on the elements. OmniClass is the most detailed and comprehensive one because it aims to be the standard for organizing all construction information.

A Finnish project management process diagram and an American precast concrete process diagram are analyzed from the Tekla Structures 4D model users' point of view. Linking objects to classification systems in CAD software is possible in two principal ways: using a direct or indirect method. The classification tool in the Tekla Structures Model Organizer uses the indirect method. The Model Organizer can store predefined classification groups, but the user is free to create any number of new groups that the project requires.

Interviews performed for this study revealed what the current status of the classification system use and the shortages of the information flow between the construction industry players. A suggestion is presented about the information flow throughout the whole construction process. It is pointed out where the information about the building element enters Tekla Structures and how Model Organizer can help in keeping the information up to date and easily reachable.

Examples for cost estimation process: an approximate estimation stage and a detailed estimation stage are demonstrated with the help of Model Organizer. Filtering and reporting information based on the purchase package groups in the Model Organizer helps to create exact tendering packages for subcontractors.

As an intermediate result of this research, the author presented a conference paper at the CIB IDS 2009 conference.

AALTO-YLIOPISTON TEKNILLINEN KORKEAKOULU
Insinööritieteiden ja arkkitehtuurin tiedekunta

DIPLOMITYÖN TIIVISTELMÄ

Tekijä:	Agnes Knopp-Trendafilova		
Diplomityö:	Rakennuksen rakennemallin yhteys rakennusalan luokitusjärjestelmiin		
Päivämäärä:	18.05.2010	**Sivumäärä:**	8 + 86
Professuuri:	Rakenne- ja rakennustuotantotekniikka, rakentamistalous	**Koodi:**	T2060
Valvoja:	Professori Juhani Kiiras, Aalto-yliopiston teknillinen korkeakoulu		
Ohjaaja:	Jukka Suomi, DI, Tekla		
Avainsanat:	Rakennemalli, luokitusjärjestelmä, 4D, kustannuslaskenta		

Tutkimuksen tavoitteena on tunnistaa mahdolliset linkitykset rakennusalan yleisten luokitusjärjestelmien ja rakennesuunnittelumallin välillä. Työssä tarkastellaan rakennusalan eri toimijoiden avainprosesseja. Nämä prosessit osoittavat tarvittavat linkitykset rakennemallin ja järjestelmien välillä. Lisäksi verrataan suomalaisia, Yhdysvaltojen standardeihin perustuvia ja kansainvälisiä luokitusjärjestelmiä. Työssä tarkastellaan ja verrataan myös Suomessa ja Yhdysvalloissa käytössä olevia rakennuksen tietomallinnus (Building Information Modeling, BIM) -ratkaisuja malliperustaisen Tekla Structures -ohjelmiston kannalta.

Teoriaosassa esitellään rakennusprojektiin liittyviä lomakkeita ja prosessikaavioita Suomesta ja Yhdysvalloista sekä sovelletaan rakennetun ympäristön luokittelujärjestelmien kuvausta.

Työssä verrataan suomalaisia Talo 80-, Talo 90- ja Talo 2000 -järjestelmiä, Yhdysvalloissa ja Kanadassa käytössä olevaa MasterFormat 2004 -järjestelmää ja kansainväliseen käyttöön kehitettyä OmniClass-järjestelmää. Pääasiallinen ero MasterFormat 2004- ja Talo 2000 -järjestelmien välillä on se, että amerikkalainen järjestelmä perustuu työn tuloksiin ja suomalainen järjestelmä rakennusosiin. OmniClass on järjestelmistä kaikkein yksityiskohtaisin ja kattavin, koska sen tavoitteena on olla kaiken rakennustiedon luokittelun standardi.

Suomalaista projektinhallinnan prosessikaaviota ja amerikkalaista valmisosabetonin prosessikaaviota analysoidaan Tekla Structuresilla tehdyn 4D-mallin käyttäjien näkökulmasta. Objektien linkitys luokitusjärjestelmiin CAD-ohjelmistossa on pääsääntöisesti mahdollista kahdella tavalla: suoraan tai epäsuorasti. Tekla Structures Model Organizer -toiminnon luokitustyökalu käyttää epäsuoraa menetelmää. Model Organizer osaa tallentaa esimääritettyjä luokitusryhmiä mutta käyttäjä voi vapaasti luoda niin monta uutta ryhmää kuin projekti vaatii.

Tutkimusta varten tehdyt haastattelut osoittivat, mitä luokitusjärjestelmiä tällä hetkellä on käytössä, ja mitä puutteita on tiedonkulussa rakennusalan toimijoiden välillä. Työssä esitetään ehdotus koko rakennusprosessin kattavasta tiedonkulusta. Siitä selviää, missä vaiheessa rakennusosatieto lisätään Tekla Structuresiin ja kuinka Model Organizerin käyttö voi auttaa tietojen pitämisessä ajan tasalla ja helposti saatavissa.

Työhön sisältyy myös esimerkkejä kustannuslaskentaprosessista: summittainen ja tarkka laskentavaihe on esitetty Model Organizerin avulla. Model Organizerin hankintapakettiryhmiin perustuvat suodatus- ja raportointitiedot auttavat aliurakoitsijoita laatimaan tarkkoja tarjouspaketteja.

Tekijä esitteli tutkimuksen välituloksia CIB IDS 2009 -konferenssissa.

FOREWORD

This thesis concludes my studies at the Helsinki University of Technology (HUT), which has recently merged into the new Aalto University. The long years of university studies at Hungary (Budapest University of Technology and Economics) and Finland have formed my knowledge and understanding in many perspectives.

Firstly, I would like to thank to all the people at Tekla who supported me on taking and solving the challenging task of my master's thesis. During the two years while completing it, I also worked at Tekla, so I could constantly develop my knowledge about Tekla Structures and have a better overview of the IT solutions used in the construction industry.

I started the literature review and interviews in the autumn of 2008. With the emerging BIM solutions, more and more attention is paid to the use of classification systems in the construction industry internationally; therefore the theoretical material available has been increasing during the writing of the thesis. This resulted in a challenge to carefully select and integrate new information into my research.

The MANI Project at HUT, lead by Professor Juhani Kiiras, gave me an opportunity to meet representatives of different construction-related companies, who were aiming to solve problems similar to my topic. I especially thank to Annikki Karppinen and Matti Partanen from Lemcon Ltd who gave me very useful interviews and provided me with a comprehensive construction process diagram to base my research on. I would like to thank to all my interviewees; Finnmap Consulting Oy Jouko Niemi , NCC Rakennus Oy Ari Törrönen, Oy Alfred A. Palmberg Ab Jouni Ojala, Consolis Technology Oy Ab Pasi Salmela.

Due to my research task I could among other people from Tekla take part in the KanBIM project lead by Associate Professor Rafael Sacks of the Technion Israel Institute of Technology. I am grateful for the experience of being part of his research team for a short time.

Professor Juhani Kiiras, Heikki Haikonen and Marjo Lehtinen and Pekka Huovinen have consulted me numerous times about the development of my thesis, so I thank them for their professional and emotional support.

In addition, I would especially like to thank Jukka Suomi and Matti Tauriainen, who were my coauthors for the conference paper that was completed during the writing of my thesis. They added their knowledge and experience into my work for the conference paper as well as for my master's thesis.

I wish to thank my parents for supporting me during the long years of my studies. And I want to thank my dear husband Dari for all the love and support I got, and my 10-year-old daughter Maria, for her love and endless understanding when I had to stay away from her due to my studies.

Agnes Knopp-Trendafilova
Espoo,18 May 2010

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1 Background

With the development of software industry new solutions are emerging for supporting the construction industry. The concept of Building Information Modeling (BIM) will change and make more effective the processes in the construction industry, when the inherent possibilities are better and better exploited.
Tekla develops software solutions, products and services for customers' core business processes in building and construction and infrastructure management and energy distribution. The model-based software product of Tekla Corporation is called the Tekla Structures. The newest configuration of this product is serving the construction management and the task management at the site. Further improvement of the software is necessary for utilizing the inherent possibilities and this way simplifying construction related processes. Tekla has realized a new direction of development, which is searching for possible links between the structural model, the task management and the building classification systems.
This issue was researched by the author in cooperation with Tekla and the International Construction Business unit (HUT/ICB) at the Helsinki University of Technology in a form of master's theses in ICB. As an intermediate result of this research a conference paper was published on the conference CIB IDS 2009. The authors of the paper were Jukka Suomi from Tekla Corporation, Matti Tauriainen from HUT/ICB and the author.

1.2 Study problem

The target of the study is to identify the possible links between the generic construction classification systems (e.g. Building 2000 in Finland, MasterFormat 2004 in USA and OmniClass) and the structural design model. At the time of this study there is no scientifically or practically justified solution for the problem. Expectedly there are more dimensions of the solution because different parties of the construction industry might need different logical link to the structural model.

Processes in the construction industry are changing due to the growing utilization of Building Information Modeling (BIM) towards performing Integrated Design Solutions. The structural model of a building is a basic need for the construction processes utilizing BIM. The building elements in the design model are classified for the easier later identification. The classification could use in the future the existing generic classification systems and other user or company specific classification systems. The present study intends to identify the key processes of the different players of the construction industry, which will indicate the necessary links between the structural model and the classification systems. A newly developed link between classification systems and IT applications should be flexible to enable different parties to use different classification systems.

1.3 Aims and limitations of the study

The intention of this study is to contribute to the improvement of information exchange processes in the construction industry. To achieve this goal an empirical approach is used. Interviews are performed with experts and construction companies from Finland, and literature review is carried out in the topic. The results are tested by performing the classification on a real structural model and making inquiries from it. This can be considered as "vertical" approach. The "horizontal" cross section of the problem is the viewpoint of a single element, namely how the information is attached and retrieved from the element during the construction process.

The present study does not give a software design solution, but provides the theoretical base for an information delivery manual utilizing the new software solutions' capabilities.

The direct and indirect classification methods are discussed and compared in the study, taken into account the software intelligence and the complexity of the built environment.

The Tekla Structures, a 4D structural design software, is used for demonstration of the theoretical and practical solutions. (By adding time to a 3D CAD application one forms 4D.) The Model Organizer is a new Tekla Open API (Application programming interface) application in the Tekla Structures. The logic of the Model Organizer allows parties in construction projects to apply their own classification systems, and it can be utilized in many different ways for the benefit of all construction-related parties.

1.4 Methods of the study

The research methods of this study involve literature review and expert interviews. The literature review targeted the relevant references about Finnish and international classification systems, standards, and the latest research results on Building Information Modeling. The interviews were conducted for gaining deeper knowledge of the information flow in the construction industry, and to test the suggested solution about the classification system utilization. The aim of the interviewee search was to find the representative interviewee(s) from within each of the six interviewee groups by branch type, i.e. owners, facility management companies, contractors, subcontractors, designers, and building products suppliers. Complementary interviews were arranged with experts in the software industry, namely from Tekla Corporation. The second choice criterion implied that the interviewees would know the Tekla Structures, and preferably already used it in their projects.

1.5 Structure of the study report

The thesis consists of eight chapters. Chapter 1 shows the foundation of the thesis and informs about its objectives, limitations, and research methods.

In Chapter 2, the theoretical foundation review addresses the construction project forms, the process diagrams, the contractual agreement forms and the legal background in Finland and in the USA. The theory of classification systems and the cost modeling in the construction industry based on the classification systems are discussed.

In Chapter 3, the commonly used Finnish and USA classification systems and the related specifications are detailed. The international efforts of classification system standardization are described. The Finnish the USA and an international classification system are compared.

In Chapter 4, the users and applications of the Tekla Structures drown up in Finland and in the USA. The analysis discusses the processes of the whole construction industry in Finland, but it concerns only the precast concrete industry in the USA. The present use cases and the piloting use cases of Tekla Structures are identified, and the middle and long run use cases of the Tekla Structures are forecasted.

In Chapter 5, the concept of information flow with a classification system in the structural model is described. The concept of the predefined and the dynamic classification system is defined. Recommendations for the use of classification systems in the construction industry are laid down based on the use of dynamic classification system.

In Chapter 6, empirical testing of the utilized concepts and solutions are shown. The interviews with construction industry players are summarized by describing the information flow in the construction industry at present time. The data input and outtake in a structural model is followed up from a building element point of view. A cost estimation and a purchase package creation example is shown with the utilization of information collected in the Tekla Structures Model Organizer. An example is presented about the information flow for precast concrete production.

In the Chapter 7, the conduct and the findings of this study are summarized.

In the Chapter 8, the conduct and the findings of this study are criticized. Two sets of the recommendations are proposed separately for Finnish construction industry players and for the Tekla Structures developers.

2. THEORETICAL BACKGROUND OF THE STUDY

As a foundation of the study three generic concepts were used. The first generic concept is the grouping of construction project forms and process diagrams. Scientists and practitioners with a great variety of depth and concentrating on different areas of the construction supply chain have drawn up diagrams. The second generic concept is the description of the built environment by classification systems. The third concept is the cost modeling based on the IFC (Industry Foundation Class) 2x2 documentation.

Appendix 2 is a collection of axioms and definitions explaining the abbreviations related the BIM and classification system development.

2.1 Construction project forms and process diagrams in Finland and in the USA

2.1.1 Contractual arrangements in Finland

The three main contractual arrangements in Finland are shown in Figure 1. Some others are also used, often as a combination of the presented ones.
"The general contract is the traditional form. Architect, engineer, consultant and contractor are directly employed by the client. The contractor is only responsible for the construction, the architect and the engineer for design. Often a project administrator acts in place of the client, coordinating the construction works." (Mindt, 1995)

"In simple split contracts, the client separately employs a construction contractor (who may also be the construction coordinator), a mechanical contractor, an electrical contractor etc. In some more developed models the construction contract is split from the beginning into a substructure contract, such as concrete framework contract, external wall contract etc. (the same is possible for the mechanical contract and the electrical contract).
The total contract, variations of it also called turnkey contract or design and build contract, is mainly used for large and simple projects, where the design is not so important. The client lets all the work to one contractor who is responsible for design and construction." (Mindt, 1995).
"There are many variations of these according to the pricing method (lump sum, unit price, lump sum with some works unit priced, building on account, etc.)" (McGregor, 2001)

2.1.2 Construction process

The idea of creating construction process diagrams is ancient, but the approaches have been changing by the time. This study utilizes two construction process diagrams from different backgrounds. One is a Finnish construction management company specific diagram, and it must be recognized, that the diagram shows only one of the many possible variations, as the same company could organize the processes. The other diagram is a recommendation created by scientists, and it narrows down the scope to the precast concrete industry in the USA.

Figure 2 shows the stages of a construction project in Finland. This scheme, which is widely used in Finland, illustrates the standard procedure. In any project form all

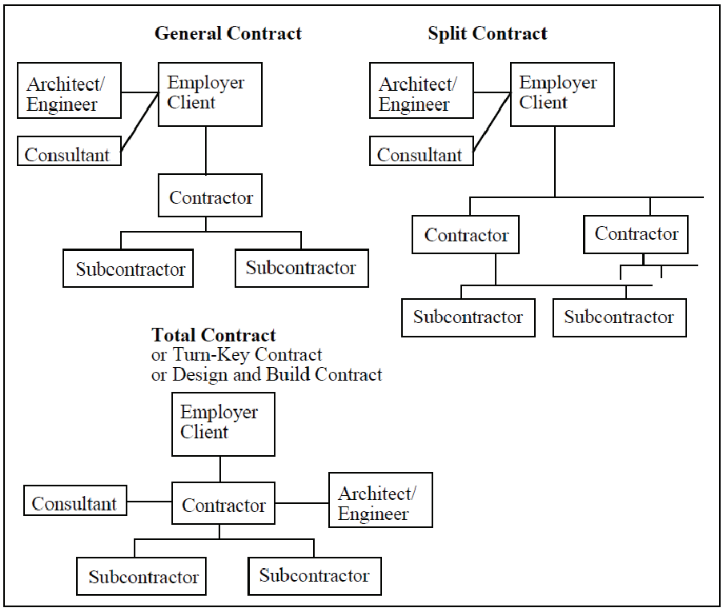


Figure 1. Main Finnish organizational forms (Mindt, 1995)

stages are required. The responsibility for the stages varies, e.g. in the design and build contract, the contractor is responsible for the three middle stages. Variations for certain special project forms are also possible.

The construction project starts with the feasibility planning stage, in which the needs of the user are identified and the cost consequences estimated. The project planning, pre-contract and construction stages follow the project decision. Step by step the various positions of the different stages are carried out till the handover decision. The occupation stage follows handover.

Normally, a program is prepared by the client for the planning of the project and, subsequently a second program for production.

2.1.3 Legal and Contractual Background in the USA

"The most common construction contract is the single contract. The architects/engineer (A/E) has a contract with the owner (client) for design services which normally includes construction contract administration. There is no contractual relationship between the A/E and the contractor. Responsibility for design and specifications rests primarily with the A/E. Construction methods and means are the responsibility of the contractor.

The multiple prime contracts form of contracting is similar to the single contract, except the work is divided among several contractors having a construction contract directly with the owner rather than to a single contractor with subcontractors. Each prime contractor may have numerous subcontractors. Division of design responsibility and detail of design and specification are similar to single contracts.

Construction management, where sharing of design responsibility sometimes takes place, is employed frequently for 'fast-track' projects. In these cases the construction

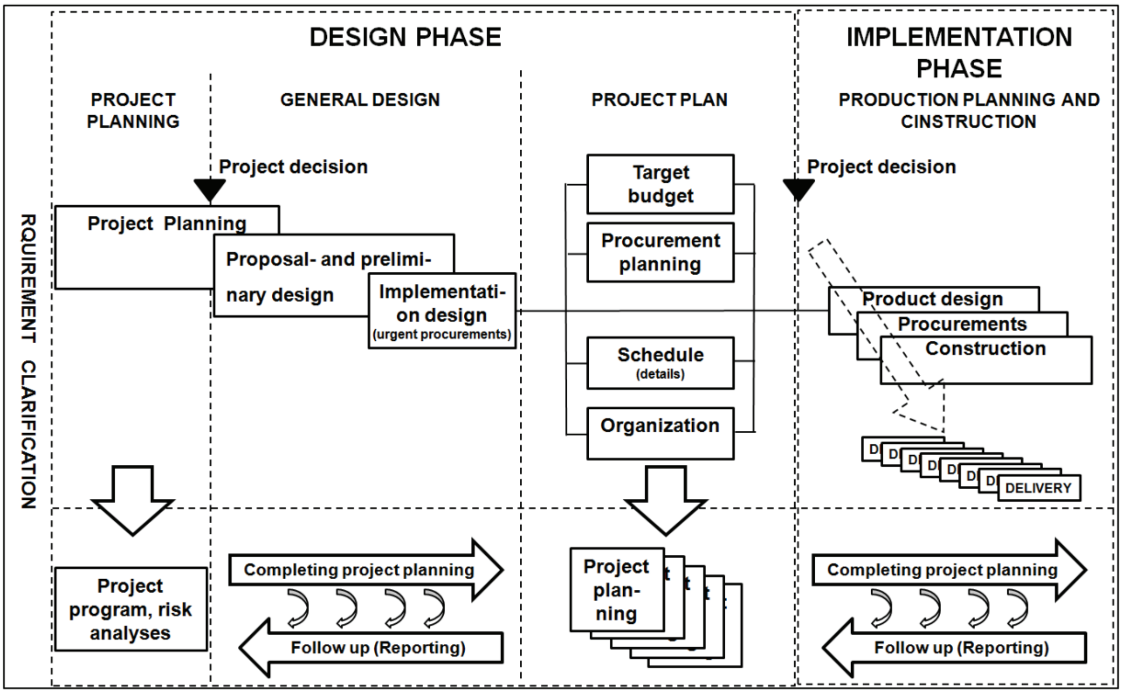


Figure 2. The chronology of a construction project in Finland (Kiiras, 2007)

manager is normally introduced to the project during early design phases to provide design and cost input and to offer suggestions for alternative construction details.

In the project management contracting method the contractor's responsibility is extended to oversight of the design process. Levels of design completeness and specification detail are carried to the extent necessary for estimating purposes and to obtain approval from local building code officials (for health and life safety). Some design functions may be carried out during construction. There is a direct contractual relationship between the A/E and the contractor (project manager).

With design-build contracting, the owner is provided with a 'turnkey' operation. The A/E is either employed by the contractor the contractor is employed by the A/E. Design responsibilities are similar to project management." (McGregor, 2001)

2.2 Theory of the classification systems

"Classification is an abstraction mechanism by which component classes can be arranged in a hierarchy, termed taxonomy. The most general classes are at the higher level and the most special classes are at the lower levels."(Jørgensen, 2010) "Composition is another abstraction mechanism about building structure, i.e. whole-part structure, by which a building is subdivided into components/parts, which again are subdivided into other components/parts etc. down to the appropriate level. Classification and composition are very different and sometimes characterized as orthogonal to each other. Classification may be very useful in modeling as the basis for identification and creation of components and, when components are created, the composition structure can be created." (Jørgensen, 2010)

“The use of classification systems has been fragmented until recent times, and mostly limited to the use for cost calculations by construction companies. There are classification systems which describe the built environment only from construction result or construction process point of view. The International Organization for Standardization (ISO) 12006-2 Organization of Information about Construction Works – Part 2: Framework for Classification of Information (later ISO 12006-2) has come into being in year 2001, which attempts to cover all the possible perspectives of the construction lifecycle. ISO 12006-2 is a framework for classification information, but it does not provide the detailed content of the tables.” (ISO 2001) Figure 3 shows the ways in which classes are related in ISO 12006-2.

2.3 Cost modeling

“Cost modeling is a process that attempts to bring design and price together. It has the objective of controlling costs, not just to measure them. Cost modeling therefore is defined to be the assessment and control of cost prior to the availability of knowledge of the element content of a project.” (Wix, 2005)

“Cost modeling is undertaken progressively throughout the design and construction of a project and makes use of the information that is available at the time. It starts at the earliest stage when information may be available only about the type of building required together with its expected overall size and location. As more detail is added to the design, cost modeling can be refined based on area measurement of spaces until estimates can be developed based on complete knowledge of the elements to be incorporated within the project.” (Wix, 2005)

In the IFC 2x2 Addendum 1, five cost modeling stages are considered for the purposes of developing exchange requirements as Figure 4 demonstrates.

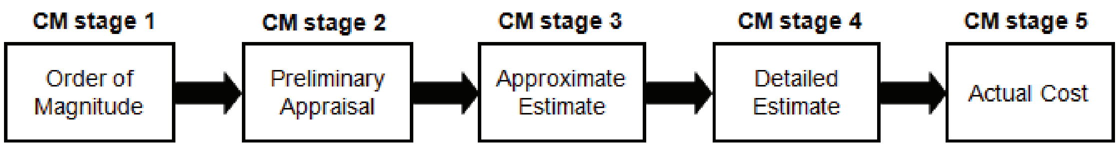


Figure 3. Cost Modeling stages (Wix, 2005)

“Note that cost modeling stages 1-4 deal with pre-construction cost planning. Cost modeling stage 5 deals with actual costs in the execution of the construction process.” (Wix, 2005)

On Figure 5 “simulation is shown about the progressive refinement of information about a project from the initial stage where all that is known is that a facility is required, through determining the type of facility, decisions on building construction such as type of structure, type of servicing and then on to the detail of the elements that will be used in building the facility such as the individual wall types, structural element types etc. “ (Wix, 2005)

From this simulation, the level of detail for costing for each of the cost modeling stages can thus be identified:

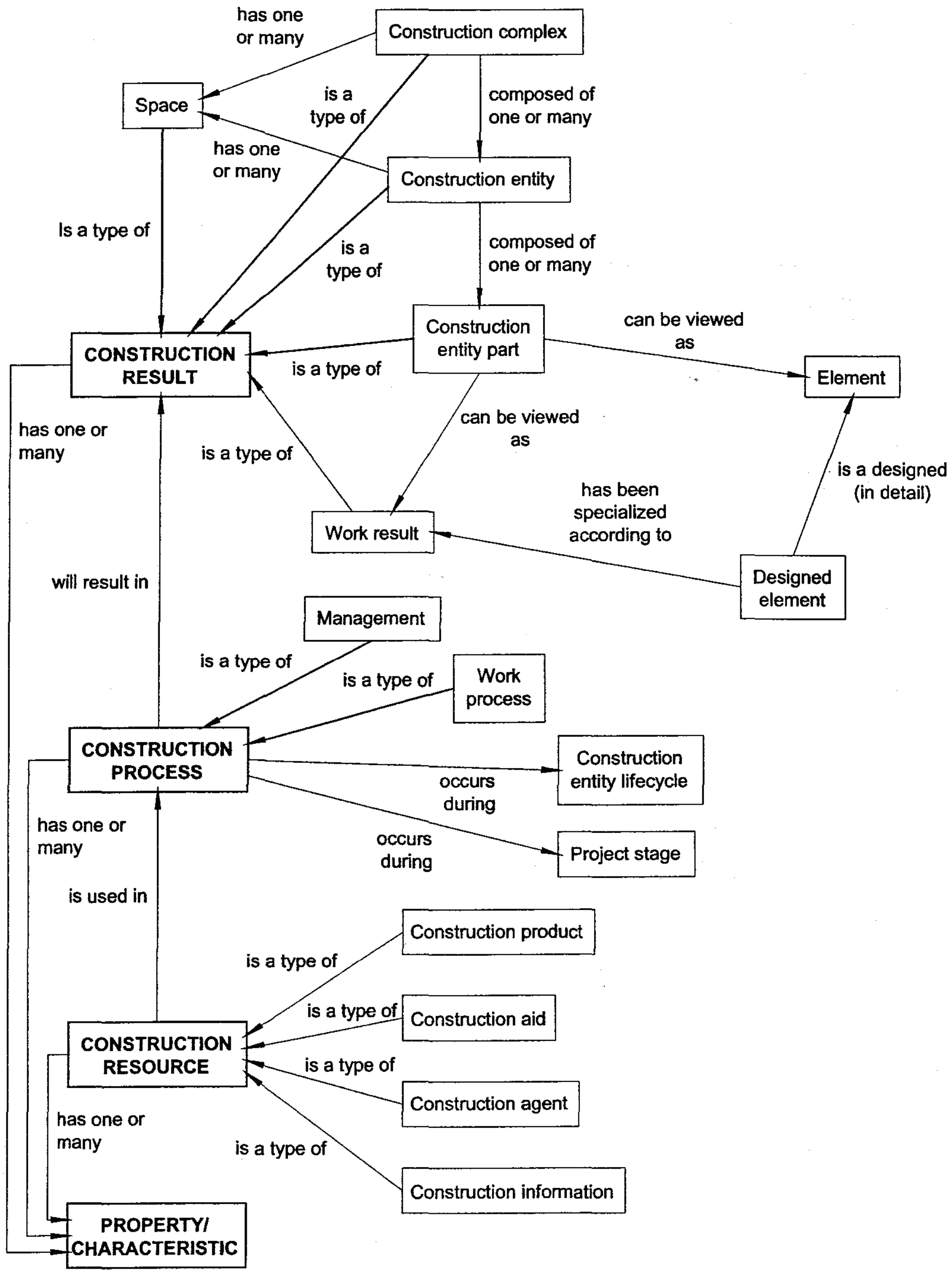


Figure 4. ISO 12006-2:2001 "Building construction- Organization of information about construction works-Part 2: Framework for classification of information"

1. Order of Magnitude 'Objects' may be limited to just a 'building' or 'civil engineering works' of a 'type' in a 'location' and the cost required is an overall budget value broken down into these major parts (e.g. external works, preliminaries and contingencies).

2. Preliminary Appraisal 'Objects' may be 'elements' of a particular 'material' and 'configuration' of building shape with broad specification and the cost required is still an overall value but broken down into the elements of the

construction project. A ‘configuration’ of building ‘shape’ means element unit quantities (EUQs) or measures of shape, such as wall to floor ratios etc. from which EUQs can be derived.

3. Approximate Estimate ‘Objects’ may be ‘elements’ that comprise a further collection of other ‘component objects’ of a particular ‘standard’ (or sub-elements). The cost required is still an overall value broken down into elements but with more detailed evidence of how that value has been deduced through detailed costs of the elemental parts of the project.

4. Detailed Estimate ‘Objects’ are as for the approximate estimate but possibly measured in more detail or with added ‘attributes’ such as ‘construction process’ which provides the basis of more accurate costing of the elemental parts of the project.

5. Actual Cost ‘Objects’ are as for the detailed estimate but are measured from their incorporation into the project. Both actual costs and detail estimates for objects may be maintained so as to provide an immediate comparison of expected and realized construction.” (Wix, 2005)

“For construction, the cost modeling stages above are expected to be approximately mapped to specific project stages according to the Table 1.” (Wix, 2005)

On Figure 6, “the process model shows the same fundamental process that is carried out for each cost modeling stage. It is only the degree of detail of information input that changes from stage to stage but the way in which cost values are handled (as either positive or negative values).” (Wix, 2005)

For each stage, the process of costing has an input requirement of quantities (either elements, resources or a combination of elements and resources) and an output requirement that includes for objects to have a related cost and for a cost schedule summarizing the cost.” (Wix, 2005)

CP Stage	Name		Project Stage	Name
1	Order of Magnitude	→	2	Outline Feasibility
			3	Substantive Feasibility
2	Preliminary Appraisal	→	4	Outline conceptual design
3	Approximate Estimate	→	5	Full conceptual design
4	Detailed Estimate	→	6	Coordinated design and procurement
			7	Production information
5	Actual Cost	→	8	Construction Information

Table 1. Specific project stages (Wix, 2005)

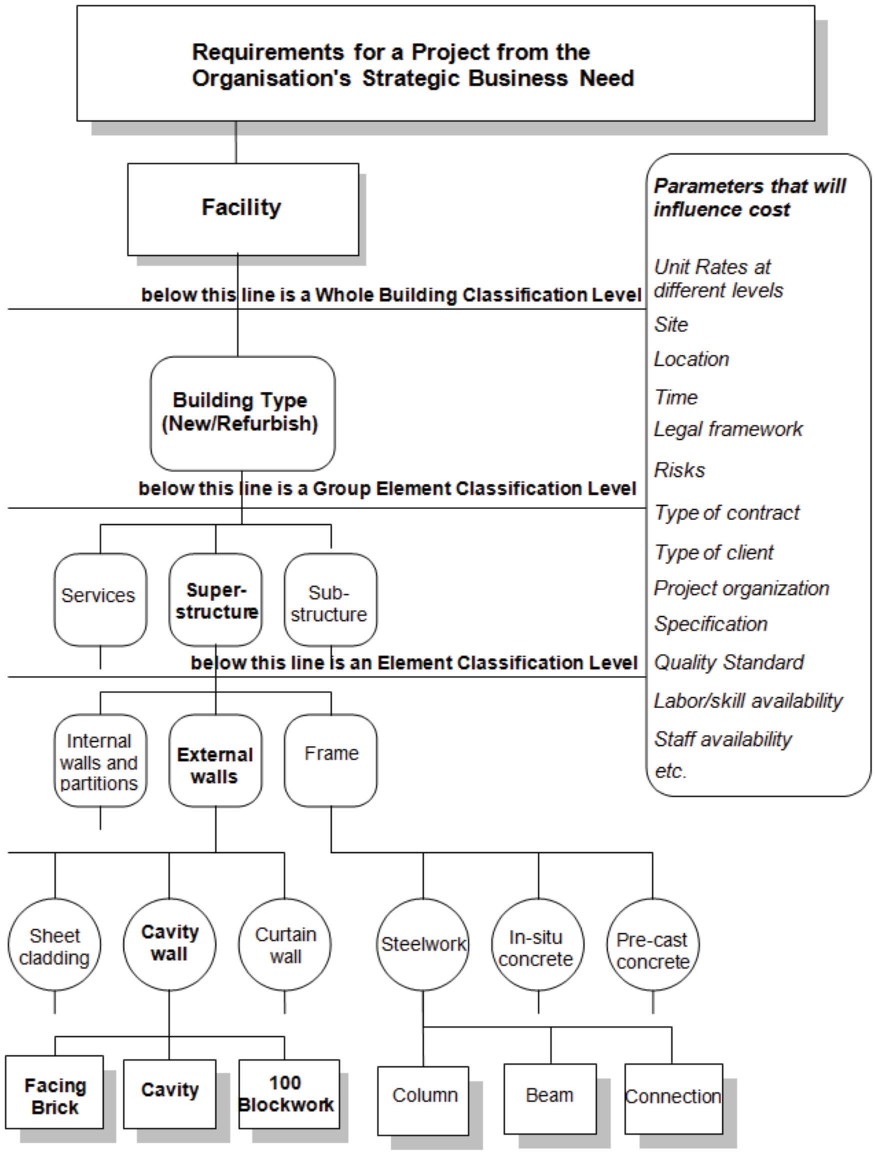


Figure 5. Requirements for a Project (Wix, 2005)

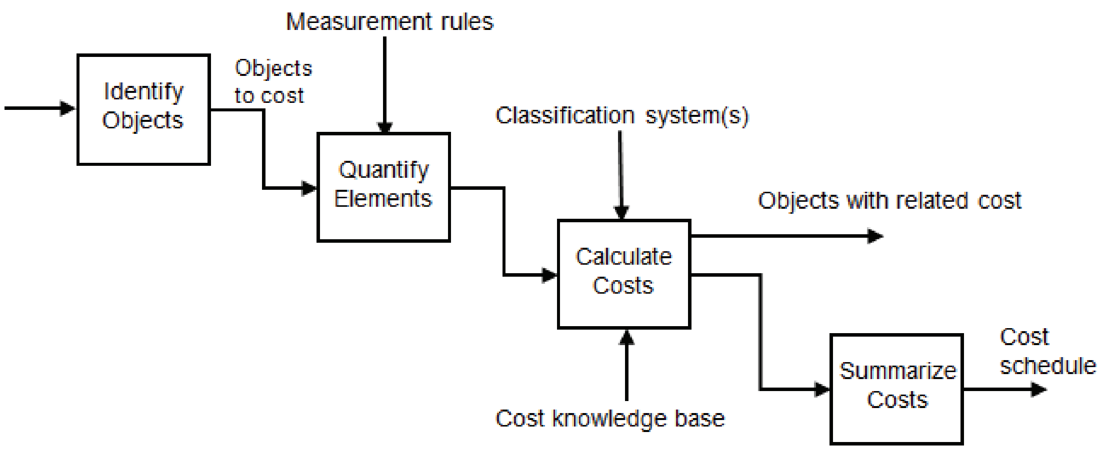


Figure 6. Process model (Wix, 2005)

3. CLASSIFICATION SYSTEMS IN FINLAND AND INTERNATIONALLY

The basis of a successful information transfer is an analysis of the construction process and a classification based on the findings. During the process, it is necessary to see the building itself and the activities linked to its production from many different points of view, each of them having its specific use and user group. (Building 90, 1999)

The extent of application of classification systems differs greatly in different countries. Within single countries there can be several independent classification systems in the construction industry. Parties of the construction industry are seeking new ways of cooperation to reach more effective operation methods. The international standards are created to support these efforts between and within different countries. National classification systems have been changed and others could be changed to follow the directions of the international standard: International Organization for Standardization (ISO) 12006-2 Organization of Information about Construction Works – Part 2: Framework for Classification of Information (later ISO 12006-2). The common understanding of classification systems will help also in international operations. The basic process model of any construction classification system, stated in the ISO 12006-2 standard, is as follows: construction resources are used in or required for construction processes, the output which are construction results. As stated in the text of ISO 12006-2, "Provided that each country uses this framework of tables and follows the definitions given in this standard, it will be possible for standardization to develop table by table in a flexible way. For example Country A and Country B could have a common classification table of e.g. elements, but different classification tables for work results without experiencing difficulties of "fit" in the juncture." (ISO/FDIS 12006-2, 2001)

3.1 International standardization of classification systems

In this chapter the come into being and the current role of CSI (Standards & Formats, Professional Development and Certification) in the USA, the OmniClass classification system, the IFD (International Framework for Dictionaries) and IFC (Industry Foundation Class) is discussed.

The Tekla Structures product supports the IFC standard. It must be noted, that although IFD Library is an emerging solution for standardization of construction information, at present time Tekla has a different approach supporting the interoperability, because the IFD Library solution is based on the direct classification method. The direct and indirect classification methods are defined in Ch. 5.1.

3.1.1 OmniClass

OmniClass is designed to provide a standardized basis for classifying information created and used by the North American architectural, engineering and construction (AEC) industry, throughout the full life cycle of buildings." (OmniClass™, 2006) OmniClass is a standard for organizing all construction information. The International Construction Information Society (ICIS) subcommittees and workgroups have developed the concept. "OmniClass is a strategy for classifying the entire built environment." (OmniClass™, 2006) "It incorporates other extant systems as the basis of its Tables – Master Format™ for work results, UniFormat for elements and EPIC (Electronic Product Information Cooperation) form products." OmniClass is built on ISO 12006-2, which provides a basic structure of three primary categories which comprises the process model:

- "Tables 11-22 to organize construction results
- Tables 23,33,34 and 35, and to a lesser extent 36 and 41, to organize construction resources
- Tables 31 and 32 to classify construction processes, including the phases of construction entity life cycles

The fifteen tables of OmniClass mapped to the suggested tables in Section 4 of ISO 12006-2 in the following way, as Table 2 presents." (OmniClass™, 2006)

Figure 7 shows a small part of the OmniClass Table 21 – Elements.

OmniClass Table 11 – Construction Entities by Function	ISO Table 4.2 Construction entities (by function or user activity) ISO Table 4.3 Construction complexes (by function or user activity) ISO Table 4.6 Facilities (construction complexes, construction entities and spaces by function or user activity)
OmniClass Table 12 – Construction Entities by Form	ISO Table 4.1 Construction entities (by form)
OmniClass Table 13 – Spaces by Function	ISO Table 4.5 Spaces (by function or user activity)
OmniClass Table 14 – Spaces by Form	ISO Table 4.4 Spaces (by degree of enclosure)
OmniClass Table 21 – Elements (*includes Designed Elements*)	ISO Table 4.7 Elements (by characteristic predominating function of the construction entity) ISO Table 4.8 Designed elements (element by type of work)
OmniClass Table 22 – Work Results	ISO Table 4.9 Work results (by type of work)
OmniClass Table 23 – Products	ISO Table 4.13 Construction products (by function)
OmniClass Table 31 – Phases	ISO Table 4.11 Construction entity life cycle stages (by overall character of processes during the stage) ISO Table 4.12 Project stages (by overall character of processes during the stage)
OmniClass Table 32 – Services	ISO Table 4.10 Management processes (by type of process)
OmniClass Table 33 – Disciplines	ISO Table 4.15 Construction agents (by discipline) *(OmniClass Table 33 and Table 34 are both drawn from different facets of Table 4.15, which then can be combined for classification)*
OmniClass Table 34 – Organizational Roles	ISO Table 4.15 Construction agents (by discipline)
OmniClass Table 35 – Tools	ISO Table 4.14 Construction aids (by function)
OmniClass Table 36 – Information	ISO Table 4.16 Construction information (by type of medium)
OmniClass Table 41 – Materials	ISO Table 4.17 Properties and characteristics (by type)
OmniClass Table 49 – Properties	ISO Table 4.17 Properties and characteristics (by type)

Table 2. Tables of OmniClass against ISO 12006-2 tables (OmniClass™, 2006)

3.1.2 CSI: Standards & Formats, Professional Development and Certification

The mission of CSI is to advance building information management and education of project teams to improve facility performance.

21-41 00 00	**Structure**
21-41 11 00	**Substructure**
21-41 11 11	**Foundations**
21-41 11 11 11	Shallow Foundations
21-41 11 11 21	Deep Foundations
21-41 11 11 41	Raft-slab foundations
21-41 11 11 61	Excavation stabilizing
21-41 11 13	**Foundation Stabilization**
21-41 11 13 11	Underpinning
21-41 11 15	**Basements**
21-41 11 15 11	Subgrade Walls (Includes: Wall Supports)
21-41 11 17	**Floors on Grade**
21-41 11 17 11	Floors Slabs-On-Grade
21-41 11 17 21	Structural Floors-On-Grade
21-41 11 17 31	Pits
21-41 11 17 41	Trenches
21-41 11 17 51	Formed Drains
21-41 11 19	**Cofferdams**
21-41 11 19 11	Sheeting
21-41 11 19 21	Sealing
21-41 11 21	**Water Control**
21-41 11 21 31	Dewatering
21-41 11 21 41	Underwater Excavation
21-41 11 23	**Roadbed**
21-41 11 23 11	Re-conditioning
21-41 11 23 21	Subgrade modification
21-41 11 23 31	Foundation Stabilizing
21-41 11 23 41	Rock Fill and Surfacing

Figure 7. A part of OmniClass (OmniClass™, 2006)

CSI is a national association dedicated to creating standards and formats to improve construction documents and project delivery. The organization is unique in the industry in that its members are a cross section of specifies, architects, engineers, contractors and building materials suppliers. The organization has 146 chapters and more than 15,000 members. (CSI, 2003)

3.1.3 IFC Standard

The strategy of the creators of the IFC standard is as follows: "The open international IFC standard defines an exchange format for information related to a building and its surroundings. GIS (Geographical Information Systems) IFC standard will include facilities to exchange GIS data, (e.g. where the building is located and information about surrounding buildings) and facilities to tag all information with a globally unique ID (GUID) from an internationally agreed ontology. With this added functionality the IFC will provide a computer understandable format in which all relevant building information can be exchanged between two parties. The IFC allows various data to be exchanged in various ways. If a receiver of information wants to be sure they can utilize the information received, the sender and receiver need to agree on exactly which information to exchange." (National BIM Standard, 2007) GIS means here Geographical Information System.

"In order to automatically verify the information in an exchange process (as described above) the information needs to be detailed further than the general level of the IFC standard. For example, if an architect wanted to supply information about the type of materials in the beams and columns this would be done in IFC using a plain text string.

Even if all of words are spelled correctly there is no guarantee that the receiving application will understand exactly what this text string means. And if a different language, dialect or form of the word is used there is no reliable way to achieve verification. Ideally the computer should be able to understand even this type of information in the IFC formatted information received. This is typically the scenario addressed in semantic searches on the web but in order to automatically interpret the semantic, the semantic needs to be described first. The IFD (International Framework for Dictionaries) (ISO 12006-3) together with the upcoming version of the IFC standard 2x4, provides a means to make this possible. The IFC 2x4 specification released in beta phase in February 2010." (National BIM Standard, 2007)

3.1.4 International Framework for Dictionaries (IFD) Library

IFD library is a unified library of terms and properties. The IFD Library for buildingSMART will be an open, shared, international terminology library for structuring object-oriented information exchange. It is being developed under the International Alliance for Interoperability (IAI) buildingSMART banner. CSI is developing a comprehensive Terminology Library and Dictionary for North America as part of this initiative, thanks to a grant from the National Center for Energy Management and Building Technology.
The IFD Library consists of an object-oriented database written in the Express data modeling language and running on the EPM Technology model server platform—a system widely used in the manufacturing industry around the world. The system provides for structured identification of commonly used terms and concepts, along with their defining properties. It assigns any defined terms a Global Unique Identifier (GUID) to enable reuse in a wide variety of structured documents and applications.
(CSI, 2009)

"At ISO meetings in Vancouver in 1999, a variety of organizations developing IT standards for the building industry (leading to what we are today calling BIM) agreed that some sort of standardized global terminology was necessary and that its structure must be useful for computers to reliably exchange data irrespective of language. As a result, the ISO committee TC59/SC13/WG6 was tapped to develop the standard now known as ISO 12006-3 – Framework for Object-oriented Information Exchange. Once ISO 12006-3 was published, STABU LexiCon in Holland and BARBi in Norway each focused their development of the object library databases to be compatible with the standard. In January 2006, the organizations signed an agreement that they would combine their separate efforts into the International Framework for Dictionaries (IFD) Library to produce a single object library / ontology that they would share between themselves for mutual benefit." (IFD, 2009)

Content – status of creation of integration of existing and creation of new content is as follows at the beginning of 2009:
"a. Integration of BARBi/LexiCon content is underway with an accurate list of duplicates identified for resolution and upload of the unique concepts progressing.
b. Norway has continued to add content to the Library for several projects related to generic products and properties to provide a link to product specific data.
c. Several projects in North America are ready to put content into the Library in conjunction with classification in the OmniClass tables." (IFD, 2009)

The below listed organizations involved with the building industry are working on initiatives and systems that address structured terminology in a variety of ways.
“1. FIATECH and POSC Caesar Association (PCA)
2. United Nations Standard Products and Services Code (UNSPSC)
3. GS1 – UPC/Bar Codes
4. The North American Industry Classification System (NAICS) – (formerly Standard Industrial Classification)
5. NATO Codification Systems (NCS)
6. Electronic Commerce Code Management Association (ECCMA)
7. bau:class (in German only)
8. ETIM International
9. OKSTRA (in German only) Object catalogue for Construction“ (IFD, 2009)

3.2 Classification and specification systems in the USA

In this chapter some major classification systems are described shortly which were chosen due to their extensive use in the USA and because of their forward looking structure.

3.2.1 MasterFormat

“MasterFormat 2004 Edition (MF04) was published by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC) in the fall of 2004. Release of MF04 marked a significant change in the construction industry as a new 50-Division organizational structure replaced the familiar 16-Division structure that dates back to 1964.” (Gulledge, et al., 2007) “Work results for heavy civil and industrial solutions have been given expanded coverage. In an effort to address environmentally responsible design initiatives, methodologies for incorporating green, sustainable, and high-performance design solutions have been mapped into the new format.” (Gulledge, et al., 2007) The definition of Work Results: “Permanent or temporary aspects of construction projects achieved in the production stage or by subsequent alteration, maintenance, or demolition processes, through the application of a particular skill or trade to construction resources.” (Gulledge, et al., 2007) Figure 8 demonstrates the divisions of MasterFormat 2004.

In Table 3 the logic of the MasterFormat numbering is explained. The scope is narrowed down to 4 levels, and also User Defined Class is recommended to be created when needed.

3.2.2 SpecLink Master Specification System

“The American MASTERSPEC specification system is organized according to the MasterFormat classification system. MasterFormat has become a US and Canadian standard classification system for written construction documentation. It is also used for product data filing and construction cost classification.” (McGregor, 2001)

“Architects, structural engineers, service engineers and interior designers in private and public offices, including federal organizations, use MASTERSPEC.” (McGregor, 2001)

“The completed specification is a self-contained project specific document. Contractors do not have to refer to the original MASTERSPEC text. MASTERSPEC

Division Numbers and Titles

PROCUREMENT AND CONTRACTING REQUIREMENTS GROUP

Division 00 Procurement and Contracting Requirements

SPECIFICATIONS GROUP

GENERAL REQUIREMENTS SUBGROUP

Division 01 General Requirements

FACILITY CONSTRUCTION SUBGROUP

Division 02 Existing Conditions
Division 03 Concrete
Division 04 Masonry
Division 05 Metals
Division 06 Wood, Plastics, and Composites
Division 07 Thermal and Moisture Protection
Division 08 Openings
Division 09 Finishes
Division 10 Specialties
Division 11 Equipment
Division 12 Furnishings
Division 13 Special Construction
Division 14 Conveying Equipment
Division 15 Reserved
Division 16 Reserved
Division 17 Reserved
Division 18 Reserved
Division 19 Reserved

FACILITY SERVICES SUBGROUP

Division 20 Reserved
Division 21 Fire Suppression
Division 22 Plumbing
Division 23 Heating, Ventilating, and Air Conditioning
Division 24 Reserved
Division 25 Integrated Automation
Division 26 Electrical
Division 27 Communications
Division 28 Electronic Safety and Security

SITE AND INFRASTRUCTURE SUBGROUP

Division 30 Reserved
Division 31 Earthwork
Division 32 Exterior Improvements
Division 33 Utilities
Division 34 Transportation
Division 35 Waterway and Marine Construction
Division 36 Reserved
Division 37 Reserved
Division 38 Reserved
Division 39 Reserved

PROCESS EQUIPMENT SUBGROUP

Division 40 Process Integration
Division 41 Material Processing and Handling Equipment
Division 42 Process Heating, Cooling, and Drying Equipment
Division 43 Process Gas and Liquid Handling, Purification, and Storage Equipment
Division 44 Pollution Control Equipment
Division 45 Industry-Specific Manufacturing Equipment
Division 46 Reserved
Division 47 Reserved
Division 48 Electrical Power Generation
Division 49 Reserved

Figure 8. The divisions of MasterFormat 2004 (Gulledge, et al., 2007)

Scope (Old Terms)	**Levels**	***MF* 1995**	***MF* 2004**
Division	Level **1**	**11**234	**11** 22 33
Broad Scope	Level **2**	11**2**34	11 **22** 33
Medium Scope	Level **3**	112**34**	11 22 **33**
Narrow Scope (If Needed)	Level **4**	1123**4**	11 22 33.**44**
User Defined (If Needed)	Level **5**	Not used	11 22 33.44.**55ABC**

Table 3. MasterFormat logic (Gulledge, et al., 2007)

based project specifications are not price able documents. Contractors prepare their own estimates of quantities for tendering. Bills of quantities are not used. MasterFormat is used to classify construction cost estimate information for construction documents preparation and tendering. A new classification system has been introduced for estimating anticipated construction costs during early design stages. This system is called UniFormat and is a "building elements" based system. UniFormat classifies construction information according to basic building elements such as substructure, superstructure, exterior closure, interior construction, building services, and site work. Some architects/engineers and constructors use UniFormat for recording actual construction costs for historical data and comparison purposes for future projects.” (McGregor, 2001)

“MASTERSPEC can be coordinated with drawings at work section level by cross reference to the MasterFormat codes. A drawing annotation system has been developed for this purpose called CADNOTES/M. This is a database of coded keynotes which extends the MasterFormat classification with a structured suffix to uniquely identify specific components or elements, e.g. ‘10160.A32 Toilet partition, metal; ceiling hung; porcelain enamel finish’.” (McGregor, 2001)

“Building Systems Design, Inc. (BSD) publishes BSD SpecLink®, which is a master specification system based on a relational database. SpecLink® fully implemented the new MF04 numbers and titles in the fall of 2004. By using a relational database approach, BSD was able to automate the transition from MF95 to MF04 by adding new fields for the 2004 numbers and titles, mapping the old numbers and titles against the new ones, and modifying its software slightly. Since the fall 2004 release of its software, users have had the ability to convert the specifications for any project from the MF95 format to the MF04 format with a single mouse click. Users can just as easily convert their project specifications back to the MF95 format, if necessary. This feature is especially useful for consulting engineers working with different architects that may not have transitioned to the MF04 format.” (McGregor, 2001)

3.2.3 MF04 Structure Online

The McGraw Hill Construction Sweets Network® now has MF04 structure available online to assist stakeholders in finding 3-Part specification content. Figure 9 shows a sample Web page capture for a search on Division 22 – Plumbing. The right hand column lists information in MF04 format. Information in the left column maintains a legacy to MF95 structure. (Gulledge, et al., 2007)

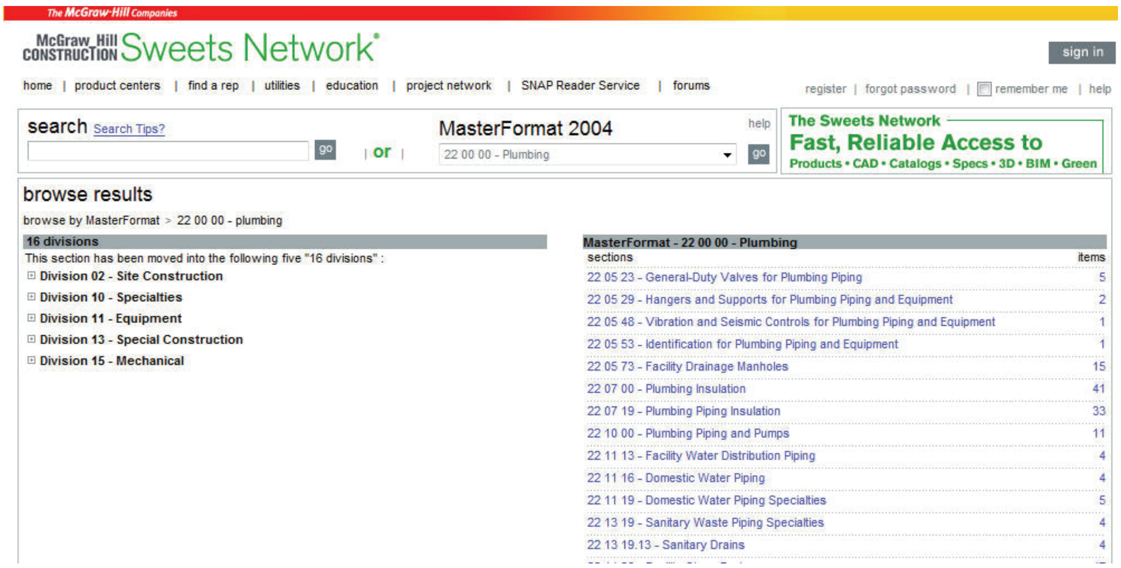
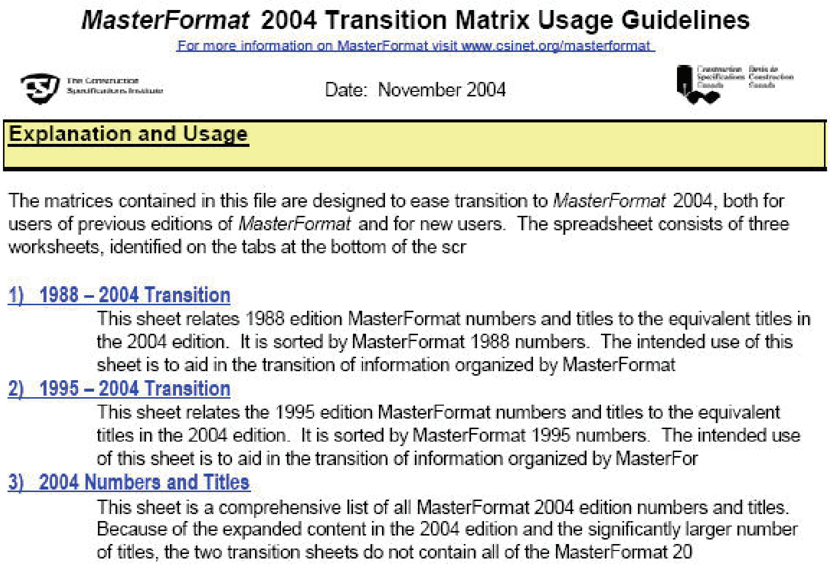


Figure 9. McGraw Hill Construction Sweets Network Division 22 Sample Search (Master Format, 2007)

There is a transition guide and a transition matrix available for helping the industry in the change. Figure 10 gives an example of the Guideline webpage outlook.


MasterFormat 2004 Transition Matrix Usage Guidelines

For more information on MasterFormat visit www.csinet.org/masterformat

Date: November 2004

Explanation and Usage

The matrices contained in this file are designed to ease transition to *MasterFormat* 2004, both for users of previous editions of *MasterFormat* and for new users. The spreadsheet consists of three worksheets, identified on the tabs at the bottom of the scr

1) 1988 – 2004 Transition

This sheet relates 1988 edition MasterFormat numbers and titles to the equivalent titles in the 2004 edition. It is sorted by MasterFormat 1988 numbers. The intended use of this sheet is to aid in the transition of information organized by MasterFormat

2) 1995 – 2004 Transition

This sheet relates the 1995 edition MasterFormat numbers and titles to the equivalent titles in the 2004 edition. It is sorted by MasterFormat 1995 numbers. The intended use of this sheet is to aid in the transition of information organized by MasterFor

3) 2004 Numbers and Titles

This sheet is a comprehensive list of all MasterFormat 2004 edition numbers and titles. Because of the expanded content in the 2004 edition and the significantly larger number of titles, the two transition sheets do not contain all of the MasterFormat 20

Figure 10. Masterformat 2004 Transition Matrix Guideline (Master Format, 2007)

3.2.4 UniFormat

UniFormat, a publication of CSI and CSC, is the Uniform Classification System for organizing preliminary construction information into a standard order or sequence on the basis of functional elements. Functional elements often referred to as systems or assemblies, are major components common to most buildings that usually perform a given function regardless of the design specification, construction method, or materials used. UniFormat users can easily understand and compare information since it is linked to a standardized elemental classification structure. The use of UniFormat can provide consistent comparable data across an entire building life cycle. The use of UniFormat's elemental framework reduces the time and cost of evaluating alternatives in the early design stages of a project, assuring faster and more accurate economic analysis of alternative design decisions. (Johnson, 2008)

3.2.5 GreenFormat

The GreenFormat webpage provides a list of construction product manufacturers satisfying certain environmental characteristics. The product list is based on the MasterFormat tables.

3.3 Classification and specification systems in Finland

In Finland there is a long history of applying national construction classification systems like Building 70, Building 80, Building 90 and Building 2000. Benefits have been realized but there is need for further adjustment of activities to fully utilize the inherent opportunities. The two commonly used classification systems at this time are the Building 2000 (used by architects) and Building 80 (used by construction companies). Building 90 and Building 2000 are very similar in structure and they support 3D modeling. Despite the widespread use of national classification system, several brakes can be recognized in the digital information flow in Finland due to the slow change towards 3D modeling. Strong efforts are currently being taken to tackle the problem with the involvement of several construction related companies. Building 2000 is the favorable choice of classification systems for the future because it supports BIM.

"Building 90 includes a complete set of classification tables for spaces, building elements, work sections and different resources as construction products, labor and site equipment. The Finnish classification systems have two major properties. Firstly, they specify a series of classification tables to be used for indexing purposes throughout the construction process. Secondly, they state a method, a wide variety of breakdowns, to be used for cost estimation and control purposes." (Building 90, 1999)

3.3.1 The Structure of Building 90

The relationships between activities and Building 90 classification tables are shown below in the Figure 11.

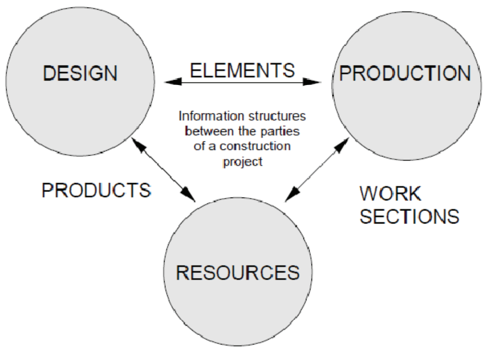


Figure 11. Relationships between activities and classification tables

"Product structures – the end product building structures – are produced in the building and mechanical design process where the building is described as elements which further are broken down into work sections. The element breakdown is used in the building specification. In the design phase, space structures are also produced. Spaces are broken down into building elements enclosing the spaces (as e.g. walls, floors and fittings) and linking them by technical services (e.g. heating service elements, telecommunication elements). The space structure approach is used in room specification and supports especially an open building system. A third structural breakdown is used in production and incidentally also in the design phase. This is production or resource structure where the elements are broken down, first into work sections and further into work methods, illustrated by construction products, labor, and subcontracting and construction equipment. The result is called work specification and it is used in tender estimation, production estimation and control for complicated work sections when adequate references to general specifications are not available." (Building 90, 1999)

3.3.2 Principles of Building 2000

"The Building 2000 classification system is based on the following principles:

- The classification functions as a tool in information transfer between the parties of the project.
- The classification supports information technology in the building process and building information modeling.

- The building can be clearly seen from the point of view of design, production or maintenance.
- The building is presented according to construction and service elements.
- The production is presented according to building resources.
- Any classification table describes completely the costs of branch of knowledge.
- The classification complies with ISO 12006-2 and is suitable both national and international projects.

Building 2000 classification system consists of six classification tables:

1. Premise and Space Classification table
2. Building Element and Project Classification table
3. Construction Work Section Classification table
4. Construction Product Classification table
5. Worksite Equipment Classification table
6. Building Resources Classification " (Building 2000)

A more detailed translation of the tables can be found in Appendix 3. "When applying the Building 2000 classification system, the Building Element and Project Classification table is used during the design and construction phase. For the preliminary specification of elements, the tables of elemental bill and estimates and tender cost estimates are used. The tender cost estimation is based on an elemental bill, which may be itemized by activities when needed. The target estimation is based on a schedule of work sections." (Building 2000)

3.3.3 The National Specification System: RYL

The Finnish specification system consists of two main document groups:

- Project specification writing guides
- Reference specifications:
- RYL for building works
- LVI-RYL for mechanical works
- Sähkö-RYL for electrical works

"The project specification writing guides are systematic lists of priceable standard specification items, which are compiled by elements (building parts). The project specifications are arranged according to the national classification of building elements: Talo 90." (Mindt, 1995)
"The reference specification documents RYL are generally considered to be a code of good building practice and can be invoked by reference in project specifications (ICIS 1993, 5). RYL is part of the RT Information File". (Mindt, 1995.)
"The RT File contains all information needed by the parties to any construction project with regard to real estate development, construction planning and design, production, building maintenance and the construction products industry.

RYL is arranged in seven parts which are subdivided into chapters describing work sections:
- Preliminaries chapter 0
- Site work chapters 1-9
- Structural work chapters 10-23
- Supplementary component work chapters 24-25
- Finishes chapters 26-50

- Fixtures chapters 51-52
- Services chapter 53

The RYL chapter numbers do not have a classifying character as they do not cover all possible work sections, but only those generally used.” (Mindt, 1995.)

“The specifies (normally the architects) use the ’Specification Writer’s Guide’, which contains a complete list of building element items arranged according to TALO 90 codes. Each item heading has a short description of the contents of the specification item and a complete list of applicable references to the RYL and national standards (ICIS 1993, 11)”. (Mindt, 1995)

3.3.4 Links between the Finnish Specification System and Other Documents

“The Finnish specification system is linked both upwards and downwards in the construction process. This is achieved by using the element method instead of work sections. The construction process starts from the client’s needs, which are defined in the brief and the room program. From the program is calculated a so-called target price. The program is also starting point for design which results to drawings and a preliminary specification. From these is calculated an element cost estimation which is compared with target price to control the affectivity of the design solution. On subsequent design phases the design is completed into tendering drawings and final specification. The quantities are measured and the tendering prices defined from these. The element method is in use.” (McGregor, 2001)

3.3.5 The Finnish cost information system

“The only Finnish cost information system is jointly provided and published by the Finnish Building Centre and the ’Haahtela Development Stock Company’. It is published yearly in the form of different books and for computer. The system includes cost information by spaces, elements and certain work sections. Cost estimation by spaces is used in the project planning stage and cost estimation by elements in the design stage.

On large projects, cost consultants may be hired by the client to check the drawings and the specifications of the architect and the prices of the contractor. They then do the costing for all project phases.” (Mindt, 1995.)

Building elements are designed according to the Construction Works Classification. For that purpose, building elements are divided into structural elements whenever several types of construction work are required to produce a single building element. A structural element comprises one or more construction products as well as their installation and installation products. The classification is suggestive and should be applied after due deliberation on a case-by-case basis. The principles of quantifying building elements have been made independent of design and production solutions, and the measured quantities usually differ from output. Thus, for instance, an external wall assembly is always measured the same way and on the same bases. The different outputs required to construct a building element are determined as required by the design solution. For instance, if the external wall assembly includes masonry, the masonry can be considered part of the quantity of the external-wall building element which is notified as an output.

3.4 Conclusions on the presented classification systems

3.4.1 Comparison of OmniClass and Building 2000

The extent of Building 2000 is narrower than the extent of OmniClass. Building 2000 does not cover the classification for infrastructure, and as visible from the table titles, the Construction Entities by Form, Spaces by Form, Phases, Disciplines and Organizational Roles; while OmniClass does cover the whole built environment. Also the depth of Building 2000 stays at a more general level with its 4 digit code within the tables, while OmniClass has the maximum of 8-digit code within the tables. Table 4 organizes the table titles of Building 2000 and OmniClass in three groups based on the standard ISO 12006-2. The groups describe the basic dimensions of classification systems, like Construction Results, Construction Processes and Construction Resources. The Building 2000 tables are organized differently than the OmniClass tables. The content of Building 2000 tables can be paired with one or more similar OmniClass tables.

<table>
<tr><th>OmniClass tables</th><th>Basic dimensions of general classification</th><th>Building 2000 tables</th></tr>
<tr><td>Table 11 – Construction Entities by Function</td><td rowspan="6">Construction Results</td><td>In Premises and Spaces Classification</td></tr>
<tr><td>Table 12 – Construction Entities by Form</td><td>--</td></tr>
<tr><td>Table 13 – Spaces by Function</td><td>In Premises and Spaces Classification</td></tr>
<tr><td>Table 14 – Spaces by Form</td><td>--</td></tr>
<tr><td>Table 21 – Elements</td><td>In Building Element and Project Classification</td></tr>
<tr><td>Table 22 – Work Results</td><td>In Construction Work Section Classification and in Building Resources Classification</td></tr>
<tr><td>Table 31 – Phases</td><td rowspan="2">Construction Processes</td><td>--</td></tr>
<tr><td>Table 32 – Services</td><td>In Building Element and Project Classification</td></tr>
<tr><td>Table 23 – Products</td><td rowspan="7">Construction Resources</td><td>In Construction Product Classification</td></tr>
<tr><td>Table 33 – Disciplines</td><td>--</td></tr>
<tr><td>Table 34 – Organizational Roles</td><td>--</td></tr>
<tr><td>Table 35 – Tools</td><td>Worksite Equipment Classification</td></tr>
<tr><td>Table 36 – Information</td><td>--</td></tr>
<tr><td>Table 41 – Materials</td><td>--</td></tr>
<tr><td>Table 49 – Properties</td><td>--</td></tr>
</table>

Table 4. Relation between the tables of OmniClass and Building 2000

3.4.2 Main differences between the North American and the Finnish base classification system

The mostly used North American classification system MasterFormat 1995, 2004 are based on Work Results, while the Finnish Building 70 – 2000 are based on the Elements. While MF04 has 8 digit depth, the Building 2000 has 4 digits. MF04 has 50 tables, while Building 2000 has 6 because MF04 covers a much greater scope, aiming to cover the whole construction industry and building life cycle.

3.4.3 Similar transition period

One can recognize a strong similarity in the transition process of the Finnish and the USA classification system shift in the construction industry.

In Finland a shift is going on from the Building 80 to Building 2000, mostly skipping Building 90. Building 90 and Building 2000 are supporting 3D modeling, so those users do not need to make too big step anymore that has put into use Building 90 already. It happens in Finland that in one company Building 80, 90, and 2000 are used besides other classification systems for mechanical engineering. This requires great effort to harmonize the data in the computing systems and to reach synergy from them.

In the USA transition is happening from MF88 and MF95 to MF04. The authors of the ”MasterFormat 2004 Edition 2007 Implementation Assessment” draw the following conclusions.

“Our final synopsis indicates the MF04 conversion process is still in transition and the five-year conversion window envisioned by CSI was realistic. As confirmed by testimonial, proactive practitioners have embraced the new structure and are aggressively applying its use in their everyday practice.” (Gulledge, et al., 2007)

“Though the pace of conversion is slower than may have been expected and resistance to change is perhaps stronger than anticipated, we can see that the new structure is performing as intended for firms who have made the switch. As critical mass continues to build, it will be interesting to see how adopters will take advantage of the new “life cycle” features of MF04 that look beyond the perspective of “turning the keys over.” (Gulledge, et al., 2007)

“As for the mixed use of five and six digit section numbers in a common project manual, we are concerned with the message this communicates. Mixed use of MF95 and MF04 sections is confusing and creates a significant burden on the design team to keep work results uniquely scoped, the bidding contractors to consistently find work results within the manual, and the installation contractor to manage construction administration paperwork in two different numbering schemes. The MasterFormat Implementation Task Team (MFITT) envisioned this exact scenario and its application has been highly discouraged. Yet, in the “real world,” we see that it can and does occur.” (Gulledge, et al., 2007)

In the USA there are great efforts to support the construction companies in the change. Similar actions could be taken in Finland too.

3.4.4 Extent and depth of a classification system

The extent and depth of a classification system is adequate if it serves the needs of the users. In the case of national classification system the goal is to cover the whole built environment and the structure of the classification system must support the BIM applications. The question is, how precise or deep should a classification system be in order to enable its wide applicability within and between several parties? Based on the interviews there is no need for very detailed base classification system, because the constructor and subcontractor companies' organizational structure and working practices widely differ. They see the adequately refined classification system as their competitive advantage. They can further refine the national classification system and still they can communicate to other companies through the base classification system or through the commonly agreed refined classification system. As a comparison base, OmniClass is the deepest classification system to be used when architects or structural engineers implement the classification, but Building 2000 is already adequately a serve the Finnish industry needs.

4. USE OF THE TEKLA STRUCTURES THROUGH THE CONSTRUCTION PROCESS

In this chapter analyzing two process diagrams in the construction industry from two countries draws up the users of the 4D Tekla Structures model. A Finnish project management process diagram and a USA precast concrete process diagram are studied. Predictions are made for the future use cases of the Tekla Structures among the parties participating in the processes. The scientific definitions of information delivery manuals for construction processes are expected to be ready in the near future, as they already exist to some processes. These manuals can be used as recommendations for all the parties in construction. The role of classification systems is enabling the exact description of processes, and comprehending to the fluent information exchange between parties. The more exact picture on the application of classification system is drawn up in Chapter 5.

4.1 Construction Management process in Finland

During the first interview the representative of Lemcon Ltd, a construction project management company, provided with a general process diagram about the Finnish construction industry. It was created in the frame of a master's thesis (Kuusela, 2007), incorporating the needs and point of views of several industry players in Finland. The Lemcon CM process diagram is used in this thesis for the demonstration of the Finnish construction processes. The diagram was made from the construction management point of view; therefore there is little information about the subcontractors' role or processes. The diagram is found in Appendix 5, and the text in the diagram was translated from Finnish to English by the author.

The diagrams are drawn up in a way that on the vertical axis the construction industry parties are listed, like client, user and facility manager, architect and principle design office, structural engineer, mechanical designer and life cycle expert, contractor, subcontractor and supplier and finally authority. On the horizontal axis the time is represented during the lifecycle of the building. The titles of the process diagram figures are as follows:

1. Requirement statement
2. Project planning
3. General design 1
4. General design 2
5. Pre-construction phase
6. Construction
7. Acceptance
8. Use and maintenance

At first the current users of the Tekla Structures were recognized based on the Lemcon process diagram, then the predicted users of the Tekla Structures in the future were identified. The figures in Appendix 5 show the Tekla Structures users differentiated with color codes depending of the time of the model application. The beginning of the process diagram, the first three figures, describes the very early phase of project planning. No Tekla Structures users were identified in these phases. The identified and predicted users of the Tekla Structures are detailed in Chapter 4.2.

4.2 Tekla users in Finland

The result of the user identification is summarized in the following Figures. In Figure 12 the considered time steps are presented. The identified current users of the Tekla Structures, the current piloting users, and the users predicted in middle and long run are presented. The new users in every time step are color-coded for the easier recognition. The construction industry players, the client or developer, the user or facility manager, the architect, the structural engineer, the mechanical engineer, the contractor and the subcontractor are the potential users of the Tekla Structures. Currently there are certain companies in all the seven identified construction industry players which are using the Tekla Structures to some extent. The list of use cases presented in Figure 12 is opened up in the time steps of Figure 13.

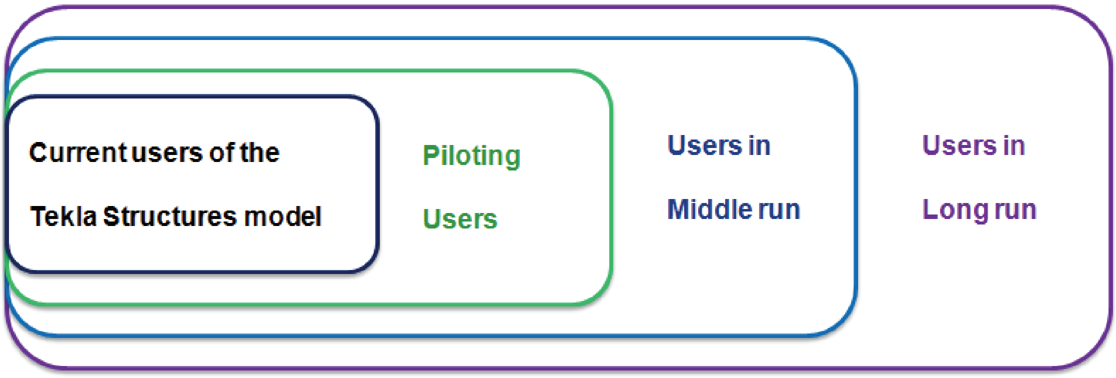


Figure 12. Time frame structure of the user mapping of the Tekla Structures structural model in Finland

4.2.1 Current users of the Tekla Structures

1.e,f. Certain clients and developers accept the design by viewing the 3D architectural models or combined models, and receive the realized structural model at the end of the construction.

Senate Properties is the best example of such owners in Finland. “Senate Properties has BIM requirements from 1 October 2007 as the first step in going over to the broader use of models. Senate Properties will further develop modeling requirements together with property owners in the Nordic countries, the USA and the Netherlands. The aim is to go over to all-embracing, integrated model-based operations in designing, building, and property servicing and maintenance.” (Kohvakka, 2006)

3. h, i, j. Architects use the Tekla Structures model for combined model viewing at several stages of the process, make clash control with the combined model between architectural, structural and mechanical model, and prepare combined model for the maintenance. Architect qualifies the subcontractors based on a 3D model.

4. a, d, g, h, j, l. The structural engineer prepares the design proposal in the Tekla Structures, and designs the structural model in the preconstruction phase. During the construction phase the structural engineer creates reports of the bill of quantities from the model, using classification information, updates the model to

Users and applications of the Tekla Structures model

1. **Client / developer**
    a. Design solution approval
    b. Project contract, invitation for tender
    c. Decision to apply for building permit based on the 3D model
    d. Approval on design solution
    e. **Acceptance of all the models / combined model**
    f. **Receives the realized structural model**
    g. Utilizing combined maintenance model
2. **User / facility manager**
    a. Comments on the design before construction
    b. Linking of the maintenance model to the maintenance manual
    c. Utilizing combined maintenance model
3. **Architect**
    a. Preliminary architectural model for evaluation of options
    b. Building permit application
    c. Creation of the architectural model in the frame of a combined model
    d. Combined model viewing and adjustment at early design phase
    e. Contractor's building solution check and approval
    f. Model update to the chosen solution, product model
    g. **Review of partial combined model**
    h. **Subcontractors qualification**
    i. **Clash control**
    j. **Prepare the combined model for maintenance**
4. **Structural engineer**
    a. **Design proposal**
    b. Consultancy on space reservation
    c. Creation of the structural model in the frame of a combined model
    d. **Design of structural model**
    e. Combined model viewing and adjustment at early design phase
    f. Production equipment planning
    g. **Bill of quantities**
    h. **Model update to the chosen solution, product model**
    i. Model update with the planned time schedule information
    j. **Contractor's building solution check and approval**
    k. Model information update during implementation
    l. **Model updating to realized model**
    m. Maintenance model
    n. Update of the model during lifecycle
5. **Mechanical engineer**
    a. Consultancy on space reservation
    b. Creation of the mechanical model in the frame of a combined model
    c. Model update with the planed time schedule information
    d. **Bill of quantities**
    e. **Contractor's building solution check and approval**
    f. **Model update to the chosen solution, product model**
    g. Model updating to realized model
6. **Contractor**
    a. **Bill of quantities**
    b. **Cost estimate**
    c. **General time schedule**
    d. **Bid package distribution**
    e. **4D time schedule, 3D site plan**
    f. **Subcontractor tendering**
    g. **Budget comparison**
    h. Project contract proposal to the Client
    i. **Project plan**
    j. **Urgent product details, changes**
    k. **Tendering, offer comparison**
    l. Bid package distribution, budget and time schedule
    m. **4D work plan**
    n. **Invitation for tender for subcontractors**
    o. **Subcontractor offer comparison**
    p. **Time schedule planning and monitoring**
    q. **Assembly manufacturing plan**
    r. **Realization monitoring, model updating**
    s. **Cost monitoring for time schedule update**
7. **Subcontractor / Concrete manufacturers, Steel fabricators**
    a. **Advanced proposal**
    b. **Offer to tender**
    c. **Revision of 4D plan**
    d. **Fabrication, installation time schedule**
8. **Authority**
    a. Comments on design in the 3D model
    b. Approval based on the 3D model
    c. **Inspection with the help of the 3D model**

Figure 13. users and applications of the Tekla Structures model

the chosen solution, checks and approves the contractors building solution, updates the model to the rationalized solution and creates the product model. During the acceptance phase he/she updates the model to the realized model.

5. d, e, f. The mechanical engineer during the construction phase exports the mechanical model to the Tekla Structures and reports the bill of quantities from it for the tender invitation. He/she checks contractor's building solution and approves it, and then updates the product model to the chosen solution.

6. a, b, c, d, e, f, g, i, j, k, m, n, o, p, q, r, s. In the preconstruction phase the contractor creates the bill of quantities and cost estimation from the Tekla Structures and makes the general schedule and the bid packages. The preliminary 4D time schedule and the 3D site plan are created and communicated to the architect. Project plane is made containing the safety plan, quality assurance, schedule cost estimation and site plan. After creating the combined model the changes are instantly implemented in the model. The 4D work plan is made in the construction phase. The subcontractors are invited for tendering. The subcontractor tendering is based on the bid packages, and the budget comparison is relatively easy due to precise packages. During construction, time schedule planning and monitoring goes on. The assembly manufacturing plan is created based on the Tekla Structures. The realization monitoring, like degree of readiness, cost monitoring of invoices is done also for the acceptance purposes.

7. a, b, c, d. The concrete manufacturer and steel fabricator subcontractors make advanced proposal to the contractor in the preconstruction phase based on the client building decision. During the construction phase the subcontractor gives offer to the contractor's tender invitation, and reviews the 4D work plan. Later the fabrication and installation time schedule is also created in the Tekla Structures.

8. c. Authority inspects the building with the help of the 3D model

4.2.2 Piloting applications of the Tekla Structures in 2010

The applications in pilot phase are expected to come into broader use in the following one or two years.

1. a, b. The client or developer uses the Tekla Structures for the design solution approval, for the creation of project contract and for the invitation for tender.

2. b. The user or facility manager links the maintenance model to the maintenance manual.

3. d. The architect uses the Tekla Structures for viewing the combined model and for the adjustment at the early design phase.

4. e. The structural engineer uses the Tekla Structures for viewing the combined model and for the adjustment at the early design phase. The Tekla Structures are used also for production equipment planning during preconstruction. The model is

updated with the planned time schedule information and with the realized schedule during implementation.

5. c, g. The mechanical engineer updates the Tekla Structures model with his planned time schedule information, and updates the model at end of the construction phase to the realized model.

6. h, l. Contractor hands in project contract proposal to the client, and makes bid package distribution and budget and time schedule in the construction phase.

4.2.3 Users and applications of the Tekla Structures model in middle run

The expected broadening of applications of the Tekla Structures in middle run are as follows.

1. c, g. The client will make decision for the application for the building permit based on the 3D Tekla Structures model. The client will utilize the combined model.

2. c. The facility manager will utilize the combined model.

3. b, c, e, f. The architect will hand in the building permit application partly in the Tekla Structures. The architect will create the architectural model in the frame of a combined model. The contractor building solution will be checked and approved in the Tekla Structures. The architect will update the model to the chosen solution and create the product model.

4. c, The structural engineer will create the structural model in the frame of a combined model. The production equipment planning will be started in the structural model. The structural engineer will create the maintenance model.

5. b. The mechanical engineer will create the architectural model in the frame of a combined model.

8. a. The authorities will give comment on the design based on the 3D model.

4.2.4 Users and applications of the Tekla Structures Model in long run

For long run the prediction is described below.

1. d. The client will approve the design solution base on the Tekla Structures model.

2. a. The user or the facility manager will comment on the design before construction based on the Tekla Structures model.

3. a. Preliminary architectural model will be exported to Tekla Structures for the evaluation of the structural and mechanical engineers.

4. a. The structural engineer will have consultancy on the space reservation based on the Tekla Structures model in the general planning phase. The structural engineer will update the model during the lifecycle of the building.

5. a. The mechanical engineer will have consultancy on the space reservation based on the Tekla Structures model in the general planning phase.

8. b. The authorities will give approval of the design will be based on the 3D model too.

4.3 Precast concrete production process in the USA

4.3.1 The process diagram

The limited availability of process diagrams lead to the decision of examining only the precast concrete process in the USA from Tekla usage point of view. The examined process diagram is taken from the “Information Delivery Manual for Precast Concrete” (LaNier, et al., 2009) prepared about the USA precast concrete industry, as part of “The National Building Information Modeling Standards”. In the same time it must be acknowledged that the Tekla Structures is widely used in the steal design in the USA especially in the steal detailing.

The authors of the IDMPC have made their division of the industry segment as presented bellow and on Figure 14. “Because of different project delivery methods, three different early stage processes were diagrammed, for precast as lead contractor, precast as sub-contractor, and architectural precast. One backend fabrication process was thought to cover the different front ends.” (LaNier, et al., 2009)

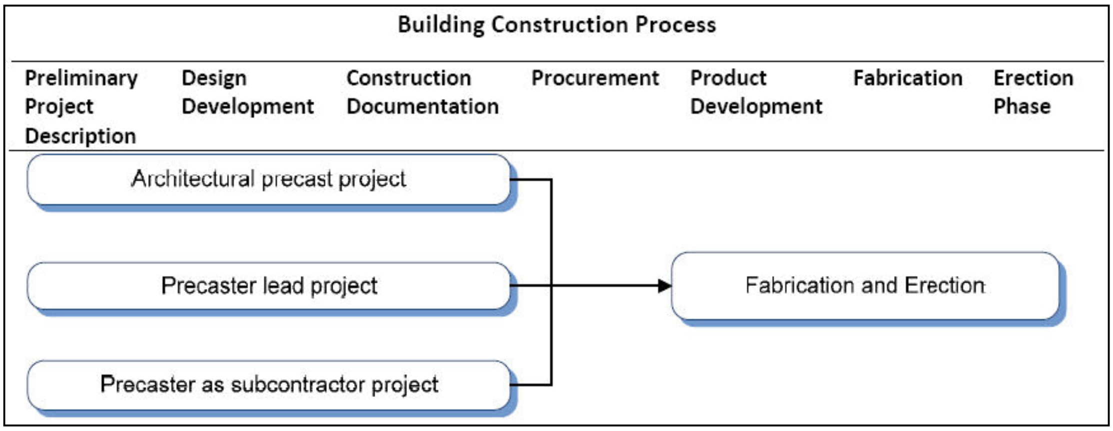


Figure 14. Precast project delivery use cases (LaNier, et al., 2009)

From Tekla point of view, the precast as subcontractor project and as the continuation, the Fabrication and erection process was studied.

On the diagrams in Appendix 6, the horizontal swim lanes are used for disciplines in the precast process together with the corresponding OmniClass designation. (LaNier, et al., 2009)

On the vertical axes of the diagrams the disciplines of the construction process and the also the document and model exchange phases between the disciplines are identified:

A. Architecture
B. Exchange

C. Engineering
D. Exchange
E. Building Product Manufacturing
F. Exchange
G. General Contracting
H. Exchange
I. Plant Management

On the horizontal axis, the phases of the project are:

1. Preliminary Project Description
2. Design Development
3. Construction Documentations
4. Procurement
5. Product Development
6. Fabrication
7. Erection Phase

4.3.2 Precast Concrete Research in the USA

Recognizing that significant improvements in the competitiveness of the precast industry might be achieved through integration and automation of their information-dependent processes, 23 North American producers formed the Precast Concrete Software Consortium (PCSC).

In the article "Process Model Perspectives on Management and Engineering Procedures in the Precast/Prestressed Concrete Industry" written by R. Sacks; C. M. Eastman; and G. Lee, the authors prepared the detailed models of information and process flow of 14 member companies of the North American Precast Concrete Software Consortium. "The modeling was performed using the authors' Georgia Tech Process for Product Modeling tool, within the framework of the consortium's effort to develop a precast concrete product model and to specify new integrated three dimensional modeling software." The findings of this research were adapted in this study also. (Sacks, et al., 2004)

"The comparative analyses expose significant diversity in the companies' processes. Some of the differences are due to differences in building or product type, contract type, and existing management software systems (such as enterprise resource planning)." (Sacks, et al., 2004)
The main company process phases are: "conceptual design, structure/assembly layout, assembly design and analysis, piece and connection detailing, fabrication, storage, delivery, and erection." (Sacks, et al., 2004)

"Three contract types appear in the models:
1. Design build, in which the precast producer has full responsibility for conceptual design. Two distinct variations exist: in the first: (1) the contract is signed soon after the start of the project, before conceptual design is complete. This demands accurate cost estimating at a stage where no detailed design information is available. In the second, (2), estimating risk is reduced as the contract is only signed after approval of conceptual design.

2. Subcontracting. Two product types are included here: (1) complete building structures, in which the precast producer must perform structural layout, design and analysis, and (2) specific building assemblies, such as facades or isolated slab systems, in which layout are dictated by the architect and engineer of record.
3. Component supply. The precast producer is required to perform piece detailing only." (Sacks, et al., 2004)

Figure 15 shows the connections between the product type, contract type, example projects, and associated precast company actives.

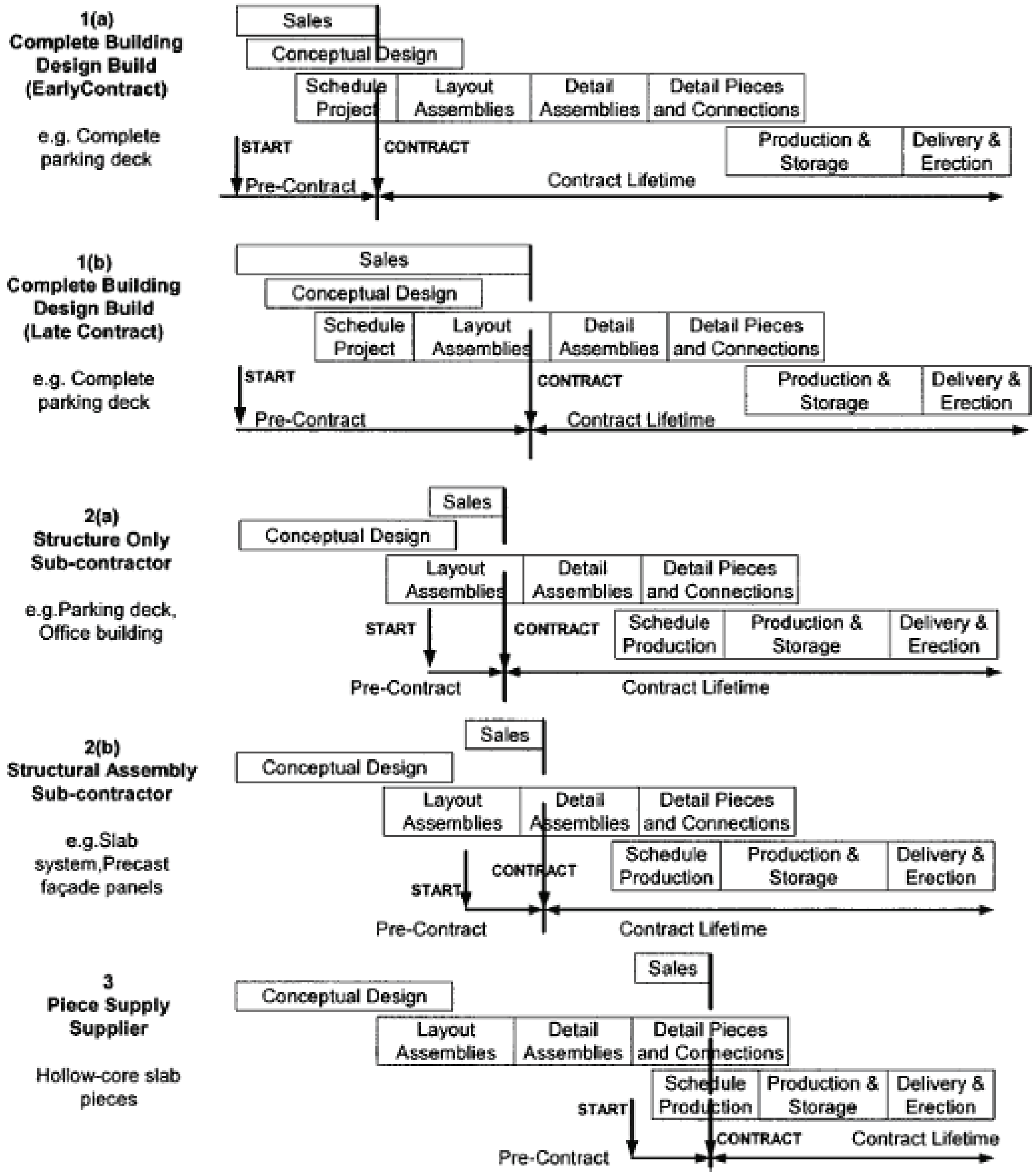


Figure 15. Product type, contract type, example projects, and associated precast company actives (activities performed by precast producer are shaded) (Sacks, et al., 2004)

"There are significant discrepancies among models with regard to the amount of detailed design performed prior to award of contract. In all cases, the precast producer must estimate the variety and quantity of pieces that will be required. Some of the companies estimate their jobs in specific cost estimating activities, which have as input only the basic information supplied by the client; others perform comprehensive general arrangement and piece design and analysis activities in order to obtain accurate quantity estimates." (Sacks, et al., 2004)

4.4 Tekla Users in USA

The process diagram recommended in the IDMPC was studied, but only those parts of the process described below, where the Tekla Structures model can be utilized. All detailed information needed precast concrete production can be automatically generated from the Tekla model. The various data can then be transferred to production planning and automation systems.

The first phase where the Tekla model appears in the project is where the Engineer prepares the Construction Documentation, and as its part, the Engineering Contract Model. "The engineering contract model focused on the structural design and integrates the structural layout with other building systems. It includes structural elements, connections and details. Both the precast and other structural systems are fully designed. The exchange is prepared as a construction drawing set or construction-level model." (LaNier, et al., 2009)

Also in the Construction Documentation phase the Building Product Manufacturer can prepare the Precast Design Model in the Tekla Structures. "The precast design model is based on the architectural and engineering designs. It includes precast slabs, beams, columns and connections. Models, drawings and specifications are submitted to the general contractor for bid preparation." (LaNier, et al., 2009)

In the Procurement phase the Building Product Manufacturer produces the detailed plans that is the "High-level description of precast piece detailing. Includes detailing of all details, finishes, joints and connections. Includes embeds, reinforcing, tensioning cable layout and block outs. Precast pieces are adjusted for fabrication, including dimensional corrections for pre-tensioning, raking of vertical mould surfaces to facilitate release and lifting hooks for lifting and transporting." (LaNier, et al., 2009)

The Tekla Structures model is merged with other trade models also in the procurement phase.

In the coordination model "the fabricator passes the coordination model of precast pieces and assemblies to the general contractor for coordination during fabrication detailing." (LaNier, et al., 2009)

In the Product Development phase the precast designer produces the precast design model. "The purpose of this exchange is to provide the detailed precast design model by precast designer for review of assembly and piece layout to both the structural engineer and architect. So the design constrains and structural loads of buildings and spaces are included." (LaNier, et al., 2009)

During the Fabrication Phase the Fabrication Model and the Structural Coordination Model is exchanged between the engineers and the building product manufacturers.

The Building Product Manufacturers produce the Precast Detailing. It "includes detailing of all details, finishes, joins and connections. Includes all embeds, reinforcing, tensioning cable layout and block outs." (LaNier, et al., 2009)

The Manufacturer delivers the detailed Coordination model to the Construction Management and the Plant Management Model to the Plant Management for Production planning.

"The fabricator passes the erection management model of precast pieces and assemblies to the plant manager to manage the erection during the erection phase." (LaNier, et al., 2009)

In the orders of piece for piece delivery "the general contractor sends the orders for piece delivery about to plant manager during the erection phase. General information about project site and buildings is included. Also there are some common categories of information for different types of products including layout, shape and material types. Finally the identification information is provided." (LaNier, et al., 2009)

In Appendix 6 the current and future use cases are identified in the precast concrete process in the USA.

In the following Figure 16 the current and future users of the Tekla Structures are listed.

Users and applications of the TS Model in a precast concrete project from the fabrication and erection point of view

1. Architect
   a. Review precast design model
2. Structural engineer
   a. Design of structural model / precast design model
   b. Structural design and reinforcement review /
      i. Fabrication model from precast detailer
      ii. Structural coordination model to precast detailer
      iii. Fabrication model from fabrication detailer *
      iv. Structural coordination model from fabrication detailer *
3. Building product manufacturing
   a. Precast peace layout /
      i. precast design model
      ii. Coordination model
   b. Precast detailing
      i. Fabrication model to precast detailer
      ii. Structural coordination model from precast detailer
      iii. Detail coordination model to general contracting
   c. Fabrication detailing
      i. Production model
      ii. Fabrication model to Structural design and Reinforcement review *
      iii. Structural coordination model to Structural design and Reinforcement review *
      iv. Erection management model **
4. General Contracting
   a. Construction coordination
   b. Construction management
   c. Manage erection
      i. Orders for piece delivery
5. Plant management
   a. Production management
      i. Production model from fabrication detailing
      ii. Orders for piece delivery from Manage erection *

* Expected realization in 2012 - 2013
** In pilot phase

Figure 16. List of the current and future users of the Tekla Structures

4.5 Comparison of the Finnish and USA precast concrete industry

The article "Process Model Perspectives on Management and Engineering Procedures in the Precast/Prestressed Concrete Industry" concludes the followings about the precast concrete industry in the USA.

"Although precast concrete offers significant potential advantages in quality, speed of erection, and cost, its share of the overall building construction market in North America is very low (approximately 1.2%) [Precast/Prestressed Concrete Institute (PCI) 2000], especially when compared with other industrialized regions. Figure 17 compares the share of reinforced concrete construction supplied by precast producers in the U.S.-only 6%-to those in European countries. The average across the European Union is 18%. (Sacks, et al., 2004)

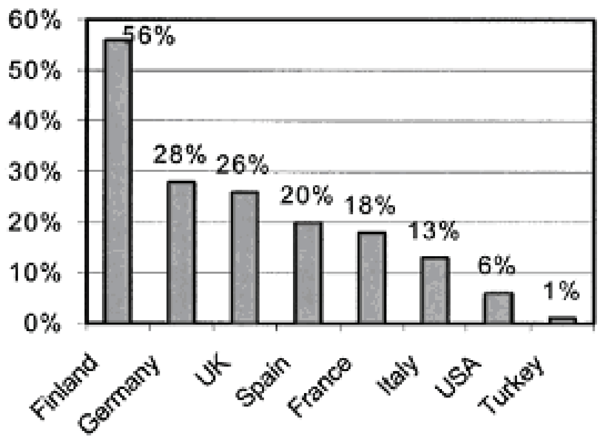


Figure 17. Percentage of total concrete production consumed in precast concrete construction. 1998 (PCI 2000) (Sacks, et al., 2004)

Figure 18 shows the U.S. market share of the industry for various building types (PCI 2000). The total is 1.2%. The largest single market is parking deck structures, with 1,010 million, representing 12.9% of the market. In contrast, in Finland, for example, 25% of all structural slabs and 11% of all building facades are precast [Finnish Concrete Industry Association (FCIA) 2000, Confederation of Finnish Construction Industries (RTT) 2000]. The influences of cost and availability of other construction types can be removed from the comparison by considering reinforced concrete construction in isolation; precast construction consumes 7.9% of the concrete produced for construction in the U.S., compared with 70% in Finland, as shown in Fig. 19. (Note: the values in Fig. 19 include concrete consumed for purposes other than construction, such as road paving, and are therefore lower.)

In the USA "Communication of engineering data remains almost entirely 2D or paper based in all of the companies." (Sacks, et al., 2004) "Currently, there is little or no use of parametric 3D modeling and data integration in the North American industry." (Sacks, et al., 2004) "Thus there is significant motivation and potential for improvement in the precast design and production process by application of information integration technologies-specifically through reengineering of the software used in the industry, to support integrated 3D based modeling of the information describing precast projects, together with development of a PCPM." (Sacks, et al.,

2004) Automated design and detailing will enable a precast producer to perform highly detailed and accurate cost estimates at extremely low cost. (Sacks, et al., 2004)

Building type	Total precast construction contracts	Total construction contracts	% precast share
Public and commercial buildings	$3,346	$143,297	2.3%
Hotels, motels, and housing	$352	$38,356	0.9%
Bridges	$640	$10,209	6.3%
Single-family houses	$13	$175,296	0.0%
Other	$443	$46,063	1.0%
Total	$4,794	$413,221	1.2%[a]

[a]Neglecting single-family houses, the precast share is 2.0%.

Figure 18. USA Precast and total construction contracts, year 2000 ($1,000,000) (PCI 2000) (Sacks, et al., 2004)

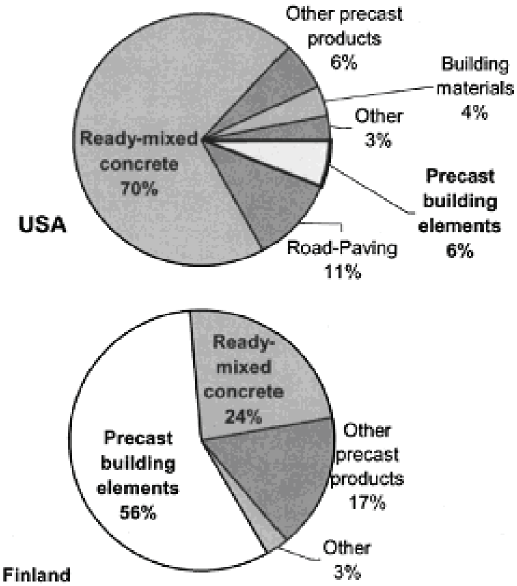


Figure 19. Concrete applications in USA and Finland (FCIA 2000; PCI 2000) (Sacks, et al., 2004)

5. CONCEPT OF CLASSIFICATION INFORMATION IN THE STRUCTURAL MODEL AND THE TEKLA STRUCTURES MODEL ORGANIZER

The theory of classification methods in CAD software is described here and it has been proved to be viable by the scientific comity of the conference CIB IDS 2009. This theory provides the base of the novel application in the Tekla Structures, the Model Organizer, and also allows the suggested flexible application for the construction parties.

“There are many types of estimates that can be developed during the design process. These range from approximate values early in the design to more precise values after the design is complete.” (Eastman, et al., 2008) “As the design progresses, interim estimates help to identify problems early so that alternatives can be considered. This process allows the designer and owner to make more informed decisions, resulting in higher quality construction that meets cost constrains.” (Eastman, et al., 2008) The use of classification information can be broadened from cost estimation to assist throughout the whole construction process, because different classification codes can be formed and stored within the Tekla Structures Model Organizer, attached to the model. The strategy for new processes in the construction industry, related to the Tekla Structures Model Organizer is formed based on the following sources: identification of the Tekla users in Finland and Tekla users in USA (in Ch. 4) and the interviewees view on the present situation of the industry (in Ch.6.1). Model Organizer can play a major role in the future as a tool for information exchange between and within the construction companies. The application of classification systems in the Model Organizer is the most recommended way of working with this tool. The national or international classification systems are based on common scientific agreement, and could serve well as the base classification system for the operations.

5.1 Theory of linking objects to classification systems

The automation of the direct linking of the 3D model to the classification brings a great benefit to the creators and users of classification information. There are several theories and implemented applications for solving this technical challenge. This study aims to present the major differences between the methods.

Object property: In this study the property of an object is understood as the minimal definitive property of the object and it is created when the object is created.

Attribute: In this study the attribute is understood as an additional property of the object, which is linked to it after creation.

In general means, depending on the properties of the objects they can be classified to different classes:

1. All red beams greater than size 10, belong to class 1
2. A red beam smaller than or equal to size 10, belongs to class 2

Once defining the classifier rules, a CAD program can do the assignment of the object to a class automatically. The program is able to handle any changes in the model by rerunning the assignments to classes or by redefining the classes. In order to use this system in practice the user has to be able to overwrite the rule and assign the object to any class.

There are two principal methods for connecting classification information to model objects.

1. Direct classification method: the classification information is stored as an attribute to each object. The nature of this connection is one-to-one.
2. Indirect classification method: the model objects and classes are connected to each other with a dependency. Dependency is typically a condition. If properties of an object match with the condition, it belongs to the class. The nature of this connection is one-to-many.

In the direct classification method, the object class is defined as an attribute of the object. Attributes and the way of linking it to the objects can be divided to two main categories:

1. Geometrical attributes are created to define the geometrical appearance of the object.
2. Non-geometrical attributes are additional information tagged to the objects.

Both main attribute categories can be used for storing the classification information.
Geometrical attributes are either linked to the objects in product libraries, or define the physical appearance of the objects otherwise. If geometrical attributes are used with direct classification, the geometrical appearance of the object is directly connected to its class. This means that the size of the object library becomes needlessly big in normal buildings having a lot of variation. All the changes in geometric appearance are reflected in the class and vice versa. Management of the library and classification becomes laborious. However this method is well suited for situations where minimal or no variation is needed in either the object library or classification (pre-engineered buildings made of standard components). A basic example is shown in Figure 20.
If non-geometrical attributes are used with direct classification, the geometry of the object is not directly dependent on the classification. The class is tagged to the object. However the automation for connecting the objects with classification system is difficult to arrange due to the one-to-one nature of the connection. The implementation

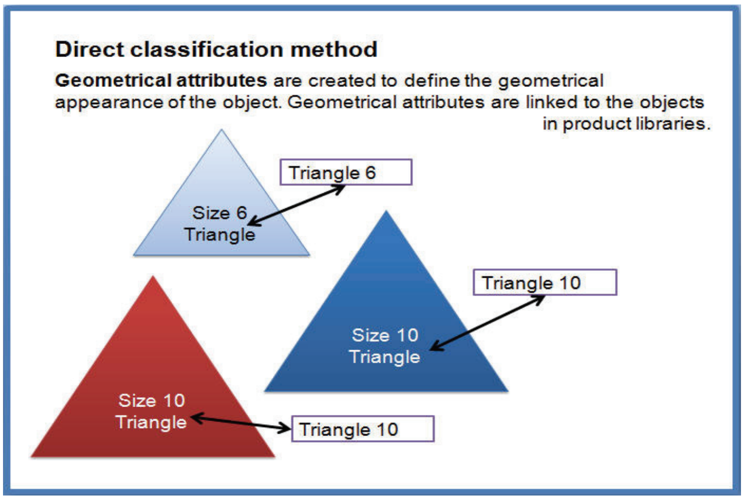


Figure 20. Direct Classification method with geometrical attributes

possibilities of one-to-many connections are limited. Deficiencies in automation capabilities in practice easily lead to situations where the end user has to manually take care of the classification validity. The link between an object and its non-geometrical attributes created with the direct classification method is demonstrated in Figure 21.

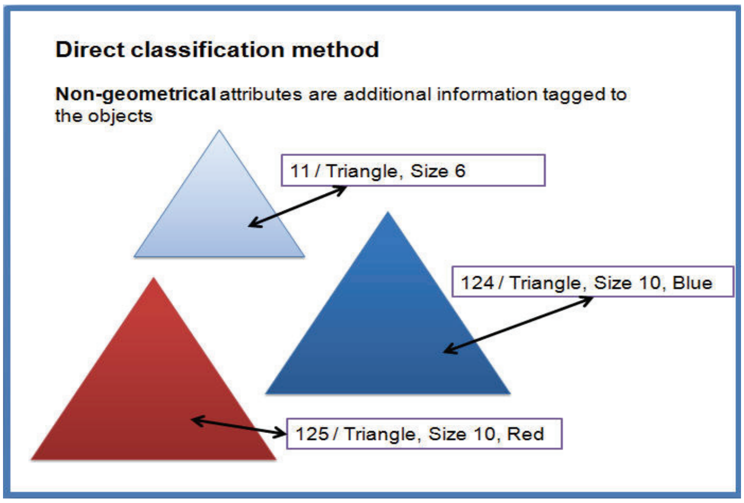


Figure 21. Direct Classification method with non-geometrical attribute

The Indirect classification method has several benefits over the direct one. With the indirect classification method the automation is easy to arrange. Objects are automatically linked to classes and automatically switched to the correct class when changes occur in the model. Objects belong to as many classes as needed, there are no theoretical limitations. The way of object filtering with the indirect classification method and the manual adjustment is shown in Figure 22.

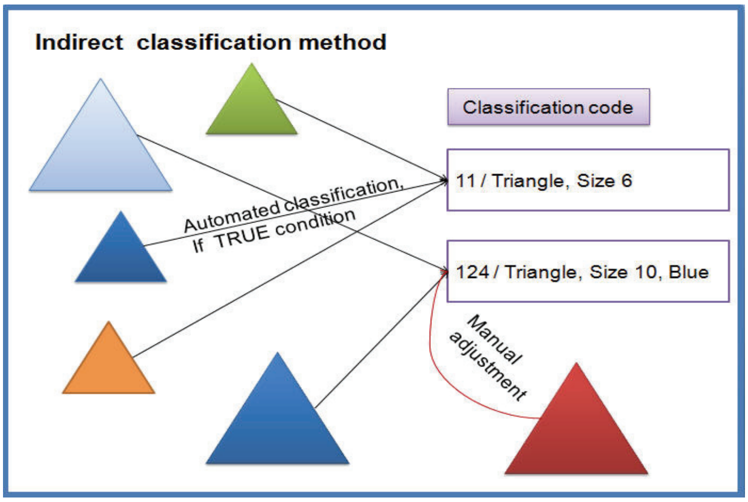


Figure 22. Indirect Classification Method

In practice automation seldom provides a 100 percent precise classification result as there is a great variation of needs, therefore the semi-automated method is suggested. Satisfactory classification functionality is reached by the combination of automatic indirect classification and the possibility of manual adjustment. The one-to-many nature of the classification does not change when manually comprehending to the process.

5.2 Concept of predefined and dynamic classification systems

CAD software of present time are capable of storing classification information about the model objects in different ways. The Tekla Structures Model Organizer can store predefined classification groups, but the user is free to create any number of new groups that the project requires. The model objects are filtered and linked to the corresponding classes in the Model Organizer.

The predefined part of the classification system is the base classification system in the Model Organizer. Structural engineers and architects deal with the predefined part. The dynamic part is the further refined classification system serving the needs of the contractor, subcontractors and other users of the 4D model. There is a possibility to agree on specific use of the classification system, and on the method of extending or refining it project by project. Contractual forms must reflect these project needs.

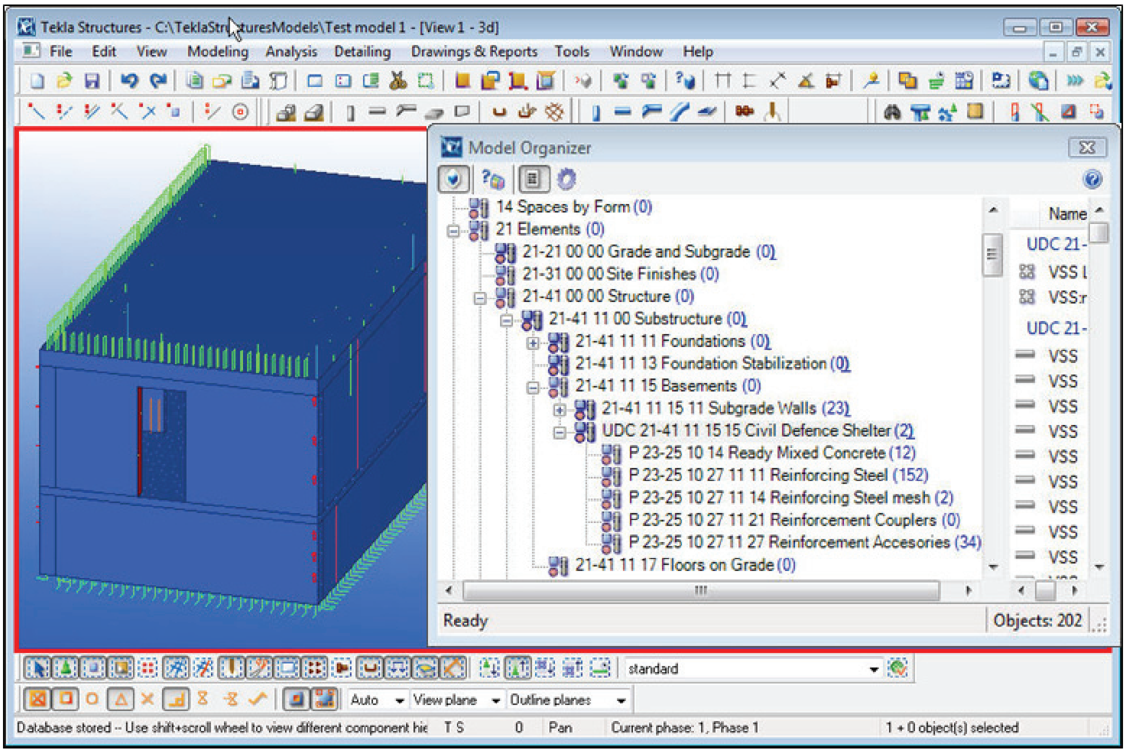


Figure 23. Classification with OmniClass in the Tekla Structures Model Organizer

As an example, OmniClass can be the basic classification system in an international project implemented in Finland and OmniClass used in the present example too. Figure 23 shows an example of classification with OmniClass in the Tekla Structures Model Organizer. Civil Defense Shelter is an obligatory part in most of a multi-storey blockhouse in Finland. OmniClass does not contain the category Civil Defense Shelter (CDS) therefore a User Defined Class, “Civil Defense Shelter”, is added to the Element categories in this project, as an example for the dynamic part of the classification structure. For the sake of cost estimation, the CDS element is further detailed with building parts, like concrete and different reinforcing parts. That is why the letter P is added in front of their OmniClass code, Fig. 24.

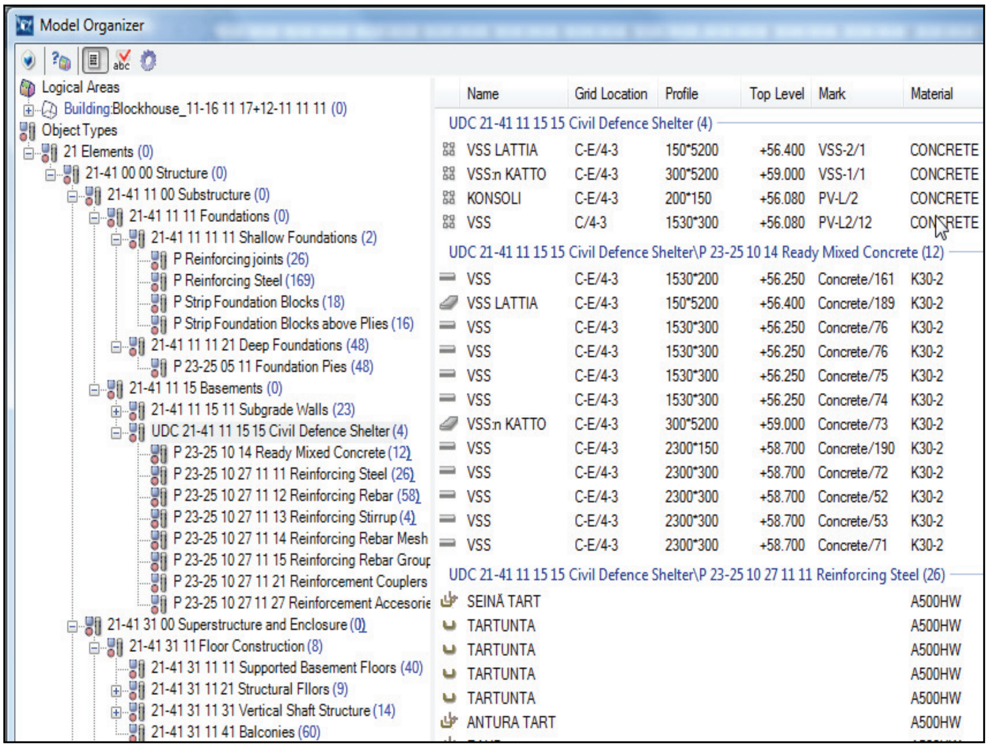


Figure 24. Products within the Building elements from OmniClass Product Table.

In Model Organizer one can extend the visible information of a class, and view several properties of the objects in the class, like name, grid location, profile, top level, mark, material, phase, area, planned erection date, weight and many more properties. Also the subclasses in the chosen class are detailed with their classification codes and objects.

Model Organizer has 3 group types, like Sections, Stories and Object Types. One object can belong to one Section, to one Story and to any number of Object Type categories. It is possible to locate an object in the model by selecting the element type, e.g. concrete wall element, and the story in question, and by clicking “Select in the model”, the Tekla Structures highlights the concrete wall elements of the given story as Figure 25 shows.

5.3 Recommendations for use of classification systems in the construction industry

With the help of 4D CAD software and the possibility to attach classification numbers to the objects in a model, the processes in the construction workflow can be better optimized. To support the information flow in the construction industry the following actions are recommended. The Finnish Building 2000-classification system is used as an example.

1. Software vendor - provides the classifier tool e.g. the Tekla Structures Model Organizer and the base classification system (Building 2000) included.
2. Owner - Agrees in the contracts with the architect and the structural designer:
    a. The architectural model contains object filtering using all four digits of the Building 2000 Elements table.

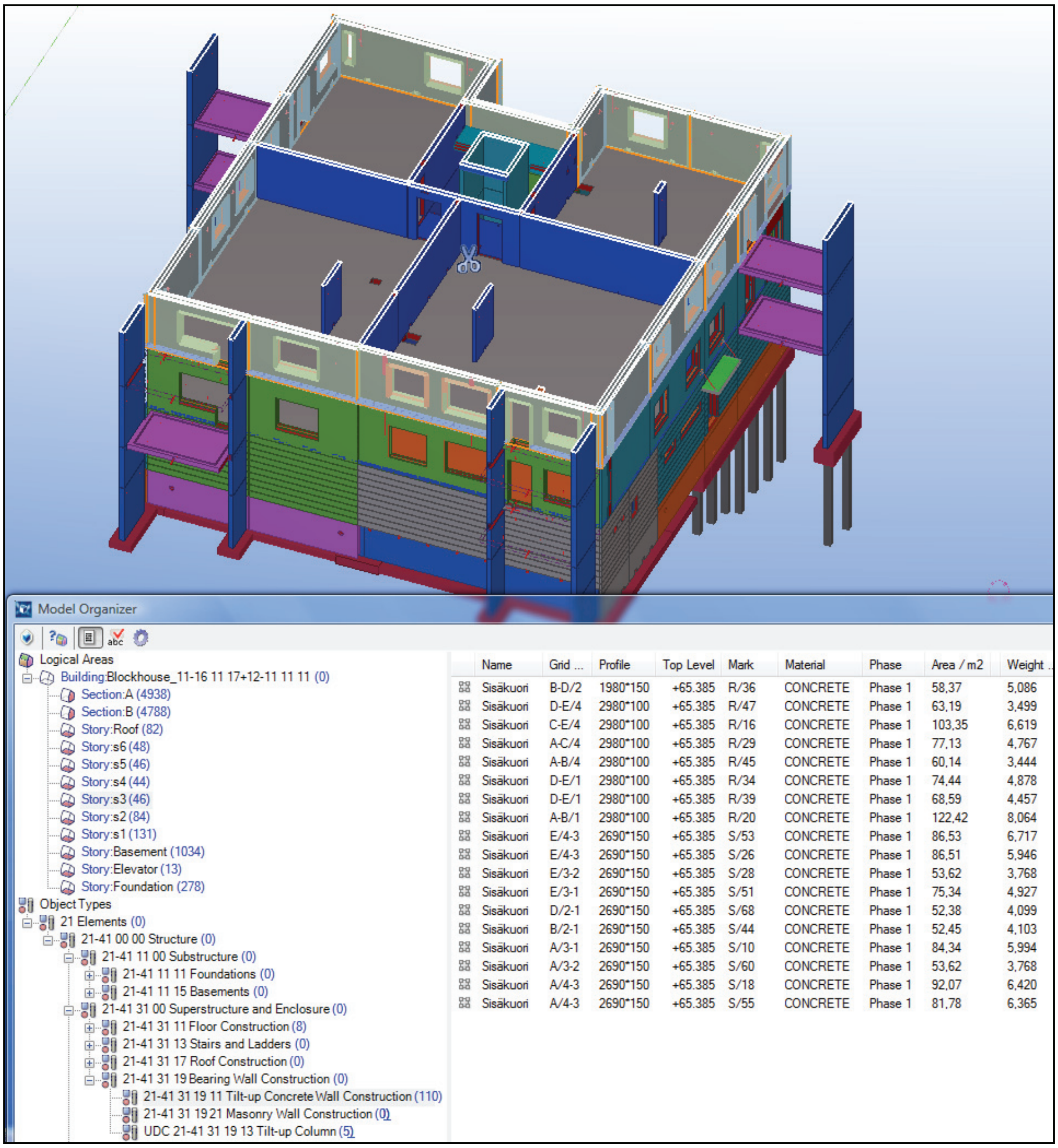


Figure 25. Selecting the union of Story 3 and Tilt-up Concrete Wall Construction

b. The structural model contains the classification of objects to the level of Building 2000, four digits.

3. Architect – classifies the objects with Building 2000 Elements to full depth (four digits). The classification information is transferred to the structural model through IFC model transfer.

4. Structural engineer – opens the imported reference model, and creates the structural model based on it. Classifies the structural and non-structural elements with the use of the Model Organizer. The base classification system with its search conditions (Building 2000 Elements to full depth) is already provided with the Model Organizer, so the engineer only runs the search functions of the Model Organizer. Model Organizer uses the classification in the object attributes to identify the non-structural reference model objects. Drawings are created based on the Model Organizer classes. The structural designer creates the combined model in the Tekla Structures based on the architectural, structural and mechanical

model. Spaces imported with the reference model are also entered into the Model Organizer. Reporting is done based on the classes in the Model Organizer. When changes are made to the model, the classification with Model Organizer is easily redefined.

5. Mechanical and electrical designer –They have attributes in their model, which can be used as a classification base, and can utilize a similar classification tool as the other parties. They utilize the classification created by the structural engineer e.g. the Building 90 in the model and complete it with RYL 2002, the classification system for mechanical engineering.
6. Contractor – Receives the model with a model sharing method. Refines Building 2000 to the level of needs in the Model Organizer. In the following points there is an example for the Contractor's process order.
   a. Bill of quantities, cost estimation, project budget creation, project schedule creation – Building 2000 Elements depth can be enough, but checking and refinement is probably needed.
   b. Bid package creation - Building 2000 Elements depth is enough for this purpose.
   c. 4D work schedule e.g. in the Tekla Structures Task Manager, or other software – easy to create tasks based on the the Tekla Structures Model Organizer classes.
   d. Subcontractor tendering – get the precise, time and work package schedule created with the help of the Model Organizer.
   e. Budget comparison and acceptance.
   f. Combining models of the contractor and subcontractor if needed.
   g. Control of implementation – the Tekla Structures Task Manager and Model Organizer is utilized, utilizing the 3D model for surveying and for measurement of object positions in the field.
7. Subcontractor - for implementation work receives 3D model. Refines Building 2000 to the level of needs in the Model Organizer. The organization of implementation work is done digitally.

   Steel fabricators and precast manufacturers - 3D model elements and project management software is used when the subcontractor is the product manufacturer at the same time. They receive 3D model. When the 3D model is received the elements are ready for production. The internal product classification is a refinement of the Building 2000, so the communication is supported with the other parties. Steel fabricators and precast manufacturers frequently use other subcontractors for the erection process.
8. Product manufacturer – receive orders and offers from the contractor. The product numbers or classes correspond to the base classification.
9. Mechanical (HVAC) subcontractor – receives 3D model from the mechanical designer, there are no clashes in the model, so there is no need for onsite changes of the plan.
10. Authority – Classification system with the 3D model will serve the building acceptance and the building inspection.
11. Facility manager – utilizes the combined architectural, structural and mechanical model for maintenance. Facility managers have a special need for the spatial classification.

5.4 Industrial impact of the new solution

The compatibility of construction-related information is increased when working on common ground within the classification systems. One of the greatest benefits of the suggested working method is that the changes in the plan are more easily handled with the use of BIM and the common classification system. Construction time can be reduced, costs can be reduced; therefore owners and developers can gain competitive advantage and give their organizations a better return on their capital investments.

6. EMPIRICAL TESTING

6.1 Interviews with experts and professionals in the industry

The interview questions were created by the author based on learning from the literature review, on the discussions with experts at Tekla and the first "free discussion" interview with the representative of Lemcon Ltd. project management company.

The questions were divided to 3 groups concentrating on the

1. experience of the interviewee and his/her employee regarding the classification systems,
2. software used in this field at the company in question, and
3. development of the classification system in use in a line with the construction process development efforts in the interviewee's company.

After the first 3 interviews a new part was added to the interview questions. The new part contained the vision of the author about the "Recommended use of classification systems in the construction industry", and it was tested and further refined in the further interviews.

Interviewees were chosen from the participants of the MANI project. MANI project was a research project lead by Professor Juhani Kiiras at HUT. The participants were the representatives of various construction related companies and researchers from the HUT. Interviews were made with the representatives of the following companies Lemcon Ltd., Finnmap Ltd., NCC Ltd., Palmberg Ltd. and Consolis Ltd. The interviewees held the following positions: Development Manager, Development Engineer, Development Manager, Quality Engineer and Project manager.

The interviewees found promising the novel concept for the utilization of the Tekla Structures Model Organizer for contributing to the elimination of information flow brakes. The concept is discussed earlier in Chapter 4.1.

6.1.1 Results of the interviews

The interviewees generally agreed on that with old types of regular projects the use of Building 80 is satisfactory, but the modeling based processes require new classification system, like Building 2000. The introduction of new software can be the force for changing and developing of processes. All the interviewees agreed that there is great need putting more effort into the construction process development, because a lot of time and money is wasted on the repeated manual data input, and information brakes. One suggestion was for industry level development that regular communication should be established between the subcontractor / supplier and the designer. Feedback is needed related to the products used, and the classification numbers of those products.

As the result of the interviews the following picture raised about the classification systems, the related software and the information flow in the construction industry in Finland in the present time.

1. Architects
    a. use 2D CAD application and provide the drawings on paper.

b. use 3D software for the design. The classification information can be linked to the objects of the 3D model. When architectural model is exported e.g. through IFC model transfer, and imported into the Tekla Structures, the classification codes of the reference model objects and spaces are readable by the program.

2. Structural engineer - creates the structural 3D model based on the 2D drawings in most cases, or imports the architectural model as a reference model and creates the structural model based on it. Based on RT (Rakennustieto, Finnish Building Information Group) recommendations, the structural engineer uses prefixes as object attributes Building 2000, RT Kortisto, RT 15-10599, 15-10600, 15-10624* are used. For classification of elements. The classification numbers of the objects are put into the User Defined Attributes (UDA). No company specific classifications system is applied.
   The structural engineer creates filters to the objects for the following purposes:
   a. owner requirements (for repeated project types)
   b. phases (layers) for self purpose: used with prefixes for drawing creation and reports

   It is up to the designer whether the Building 2000 classes are entered as attributes or not.
3. Mechanical and electrical designer – can use the 3D model created by the structural engineer as a reference model for the design. They utilize the classification created by the structural engineer e.g. the Building 90 in the model and complete it with RYL 2002, the classification system for mechanical engineering.
4. Project Management Company – usually uses Building 80 as the base of bid packaging, cost estimation and other purposes. The classification is added to the objects in the 3D model. Without 3D model and precise bid package preparation for subcontractors, the received tenders are estimative and they have great deviation in pricing. The 3D model seldom arrives before the first cost estimation is done. The classification systems are used on a very general level so the way of its utilization is not considered to be a competitive advantage.
5. Contractor - use Building 80 classification system for quantity survey, pricing and cost estimation. They are done by manual calculation or software is used. The 3D model is recreated in a chosen "quantity take off" software, and direct classification is used to support filtering. For construction scheduling and implementation monitoring, separate project management software is used, where the building objects are entered manually. In some company several separate internally developed coding systems are used. For example one coding system is based on Building 80 and the other is based on Building 2000, and they are used parallel to each other in the cost estimation, purchasing, project follow up construction works and building services. The good internally developed classification systems and the way of utilization are considered to provide competitive advantage.
6. Subcontractor - Subcontractor for implementation work receives 2D drawings or rarely 3D model, which is used for bid offer creation. The organization of implementation work is done manually and is paper-based. There are

many different types of subcontractors, so it is not possible to define a general way of working.

7. Steel fabricators and precast manufacturers - mostly 3D model elements and project management software is used when the subcontractor is the product manufacturer at the same time. They also receive 2D drawings or a 3D model. When 2D drawings are received, the 3D element model for production is created. When the 3D model is received the elements are ready for production. They use internal product classification system and ERP (Enterprise Recourse Planning) program for production planning. Steel fabricators and precast manufacturers frequently use other subcontractors for the erection process. The interviewed precast manufacturer company uses a self-developed product group numbering system for its products which does not compile with the national classification system. The product group numbering is put into the UDA of the object in the Tekla Structures, and reports can be created based on it.
8. The role of the steel fabricators and precast manufacturers is versatile in the construction industry. They can be general contractors, subcontractors for erection and they can have designers, product manufacturers, construction managers, and transportation companies as their subcontractors and also other subcontractors for the erection process. The situation is changing from project to project.
9. Product manufacturer – receive orders and offers from the contractor. Produces smaller building parts.
10. Mechanical (HVAC) subcontractor – receives 2D drawings, sometimes a 3D model. As the received model is getting more and more reliable, they are producing more prefabricated parts.
11. Authorities – require 2D drawings and do not accept 3D model.

6.2 Information exchange about a building element

A partly already implemented and partly imaginary information flow is presented in this section throughout the whole construction process. It is pointed out where the information about the building element enters the Tekla Structures, and how Model Organizer can help in keeping the information up to date and easily reachable. Figure 26 illustrates the information flow between the construction parties. The data types are noted between parentheses in the text later in this chapter.

The idea of the building element first appears at the General design phase in the preliminary architectural model (1). The architect defines the preliminary height and place of the building element (2). When the decision on the design solution is made, the architectural model is prepared. Here the exact position, material is defined for the building element (3, 4). For nonstructural elements the architect defines the dimensions, name and prefix.

The structural designer adds further properties to the building element in the structural model (Figure 27), like the exact dimensions, name, prefix, reinforcement, GUID number (Tekla Structures adds it automatically), part number, assembly number, classification grouping in the Model Organizer, construction phase, class by color coding (5 – 14). In 2009 the general practice is to use the object name, prefix and the class for selecting the objects for drawing creation in Finland. In the future the drawing creation can be based on classification information in the Model Organizer.

In the pre-construction phase the data can be easily collected from the model based on the Model Organizer classes. The contractor makes the quantity take off from the model based on the classes (16). The classes are used to define the work packages or tasks to fill in the Tekla Structures Task Manager tool for construction management purposes (17). The bid packages are formed to be suitable for the subcontractors (18).

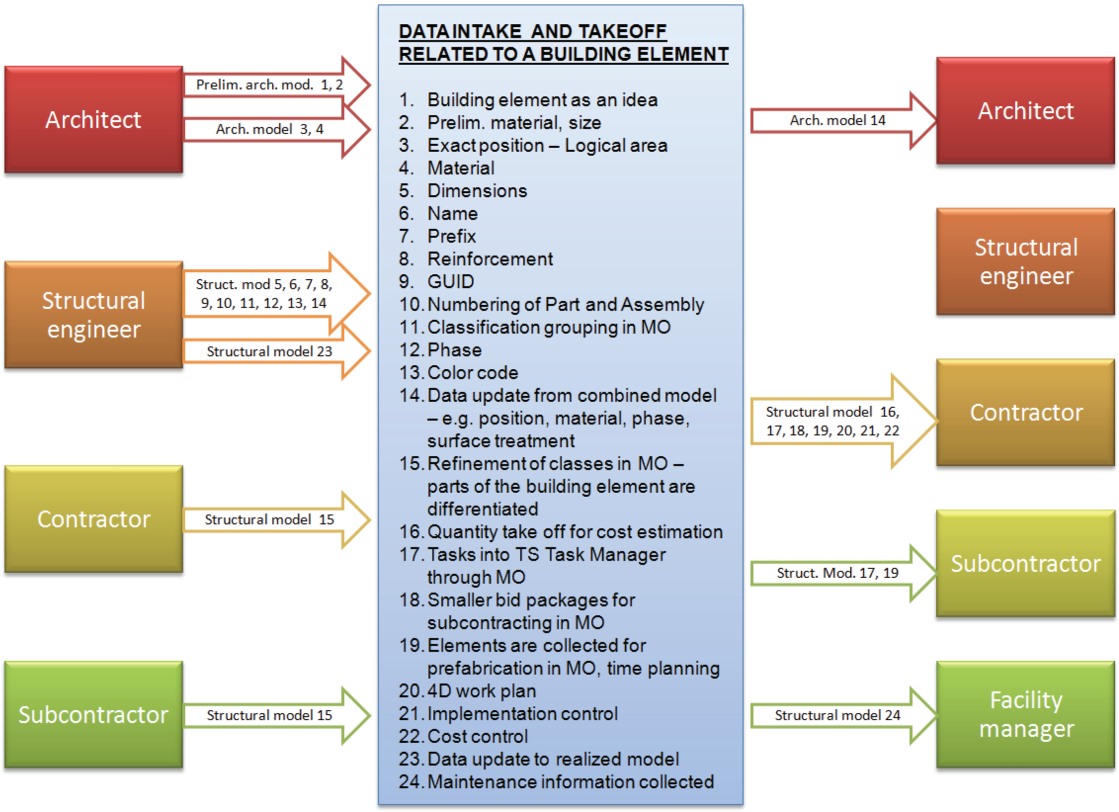


Figure 26. Data intake and takeoff related to a building element

The building element gets a price, a time frame for the erection and the subcontractor is chosen to erect it (19). The building element properties are updated in the structural model, and adjusted to fit with the combined architectural, mechanical and structural model.

During the construction phase the bid packages are distributed to the subcontractors and the 4D work plan is created (20). The subcontractor refines the classes in the Model Organizer. The building element gets subclasses e.g. main profile, surface treatment and installation fixtures. The building element properties are finalized in the structural model, and adjusted to fit with the combined architectural, mechanical and structural model. The contractor sends the 3D model elements for the prefabrication factory if elements are not casted on site. The time schedule of construction is controlled with the help of Model Organizer and Task Manager (21, 22).

In the acceptance phase the cost control and the realization monitoring are the main activities, where data withdrawn from the Model Organizer and the Task Manager is necessary (23). The maintenance model is created and the necessary information is stored about the building element (24).

In the acceptance phase the cost control and the realization monitoring are the main activities, where data withdrawn from the Model Organizer and the Task Manager is necessary (23). The maintenance model is created and the necessary information is stored about the building element (24).

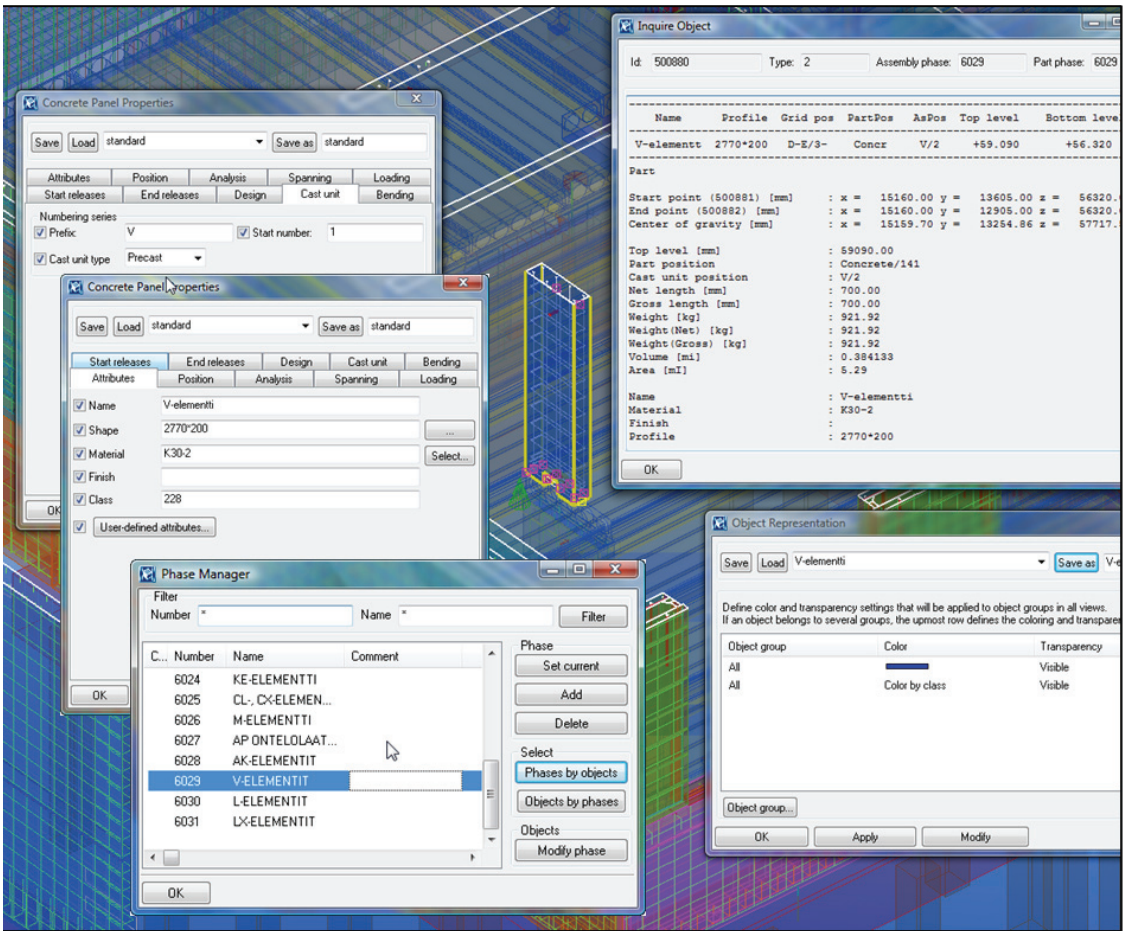


Figure 27. Attributes of a building element in the Tekla Structures

6.3 Cost estimation with the Tekla Structures Model Organizer

Quantity takeoff is done with the reports in practice in the Tekla Structures, but cost estimation in the Tekla Structures has not been the intention of the developers. However one can produce the necessary data for the cost estimation with the help of Model Organizer. The different building elements or products can be grouped in Model Organizer, as the cost estimation stages require. It is beneficial linking the data, inquired with Model Organizer from the model, to another software specialized in cost estimation, for example to Tocoman, Vico Office or MS Excel software.

A simplified model part is used for demonstration for the sake of shorter element lists in Model Organizer. Two stages of the cost estimation process, discussed in the theory chapter (in Ch. 2.5), are taken as example here: the third, approximate estimate stage, and the forth, detailed estimate stage.

6.3.1 The Approximate Cost Estimation Stages in Model Organizer

The approximate estimate stage follows or is at the same time with the full conceptual design. The elements appear without any detail. On the Figure 28 a part of the cast in place civil defense shelter is selected. The elements are collected into the Model Organizer and during the design and construction process the necessary information will be feed in under every element. And also the elements will be grouped in different ways to serve the current user's needs. As Figure 29 shows, the columns on the right side of the Model Organizer are adjustable so more and more detail can be inquired about the objects as the design proceeds.

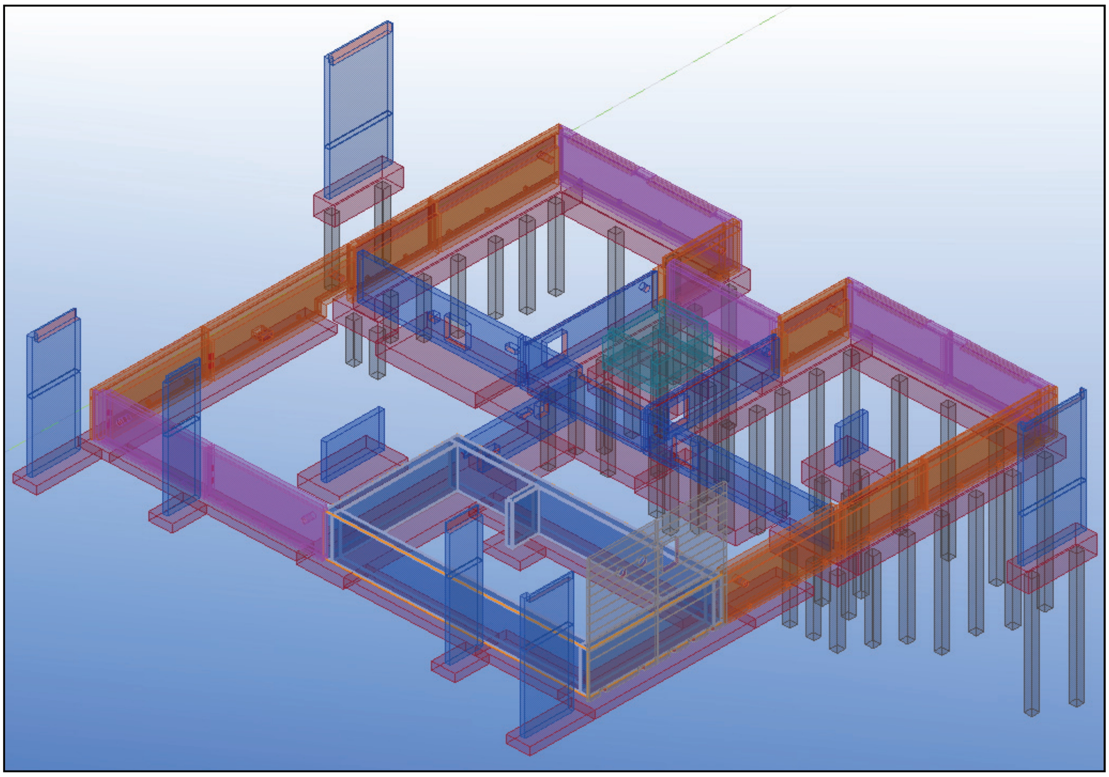


Figure 28. Cast in place civil defense shelter is selected as a building element for the approximate estimate stage.

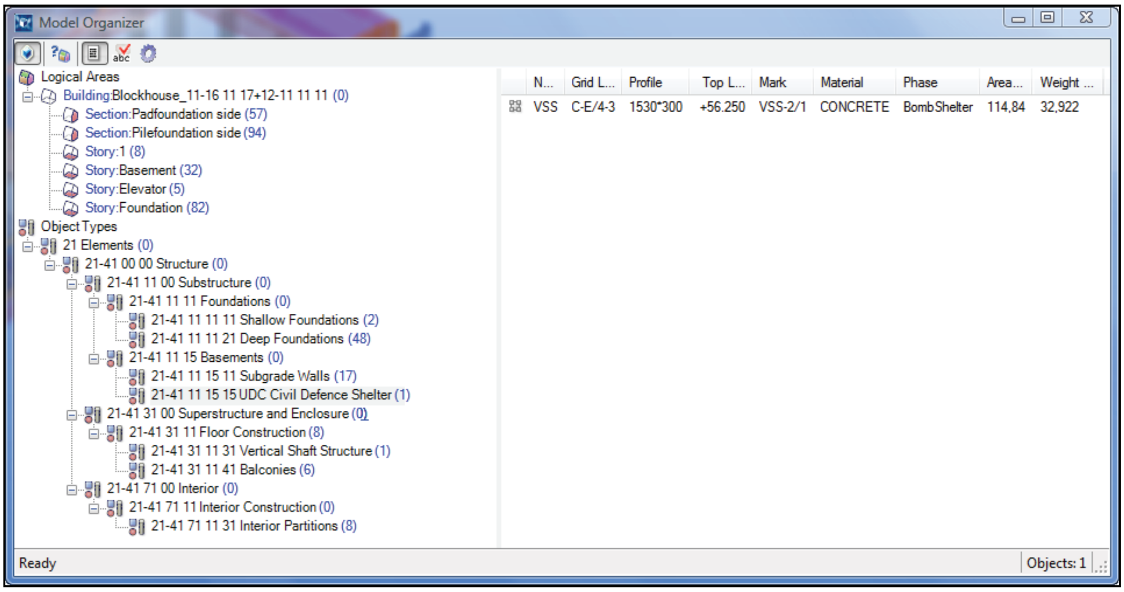


Figure 29. Inquire of the civil defense shelter in Model Organizer for approximate estimation

6.3.2 Quantity takeoff for approximate estimate stage with report in MS Excel

In the example on Figure 30, the precast concrete elements are collected into separate classification groups based on their form. The elements got different prefixes in their property dialog based on the group they belong to.

The lowest (repeated) level in the Model Organizer was necessary here because of the immature state of the reporting functionality.

Using the Template Editor program in the Tekla Structures the report was created and opened in a MS Excel sheet. The Model Organizer class, the prefix, the name, the number of elements, the summarized weight and the summarized volume are reported in Table 5.

	A	B	C	D	E	F
1	MODELORG_CLASS	PREFIX	NAME	NUM	WEIG_SUM[kg]	VOLUME_SUM[m3]
2	21-41_31_19_11__1	S1	2690*150	8	6717	4.89
3	21-41_31_19_11__2	S2	2690*150	8	5946	4.36
4	21-41_31_19_11__3	S3	2690*150	8	3768	2.74
5	21-41_31_19_11__4	R4	2980*100	4	3499	2.69
6	21-41_31_19_11__5	S5	2690*150	8	4966	3.68
7	21-41_31_19_11__6	R6	2980*100	4	4767	3.7
8	21-41_31_19_11__7	R7	2980*100	4	5571	4.31
9	21-41_31_19_11__8	R8	2980*100	4	3435	2.64
10	21-41_31_19_11__9	R9	2980*100	4	4756	3.66
11	21-41_31_19_11__10	R10	2980*100	4	3945	3.04
12	21-41_31_19_11__11	R11	2980*100	4	7429	5.72
13	21-41_31_19_11__12	R12	1980*150	12	5086	3.02

Table 5. Report of the precast elements based on the Model Organizer classes

6.3.3 The Detailed Cost Estimation Stage in Model Organizer

At the detailed cost estimation stage the recipes of the elements are made. On Figure 31 the detailed elements are visible and the civil defense shelter is highlighted.

In the Model Organizer (Fig. 32) the work results (tasks related to the element) and the products of the element are listed with their OmniClass code. This is the recipe of the civil defense shelter, and it can be completed with the cost of the work and the products in cost calculation software. The tasks (or work results) related to the building element are for example building the cast in place concrete forming, the concrete reinforcing, pouring the concrete. The products of the elements are for example the ready mixed concrete, the concrete forms, the reinforcing steel, the stirrups, the reinforcement meshes and the accessories. The work results are noted with “W” and the products are noted with “P” in the Model Organizer beside their OmniClass code.

6.3.4 Purchase Packages in Model Organizer

Filtering and reporting the information based on the purchase package groups in Model Organizer helps creating exact tendering packages for subcontractors. In Finland the most usual way would be the fixed price contract with the subcontractors to produce the cast-in-situ civil defense shelter. Usually the precast concrete fabricator produces the detailed plans of the concrete elements, and erects the elements.

On Figure 33 one possible example is shown of the purchase packages created from the products and work results of the civil defense shelter. There are three subcontractors, for concreting, concrete forming, and reinforcing. They all deliver the material and install it.

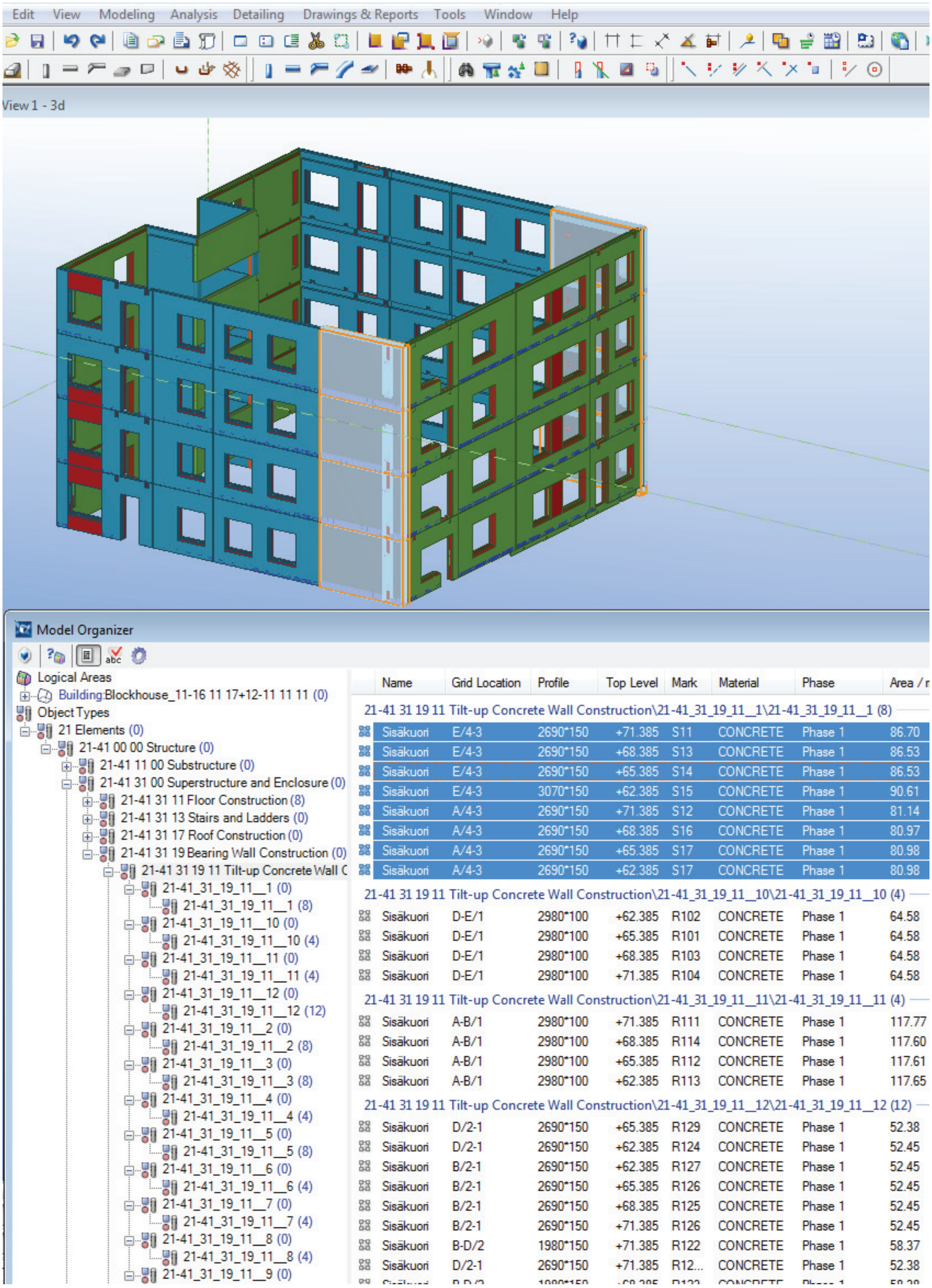


Figure 30. Quantity takeoff in Model Organizer for approximate cost estimation

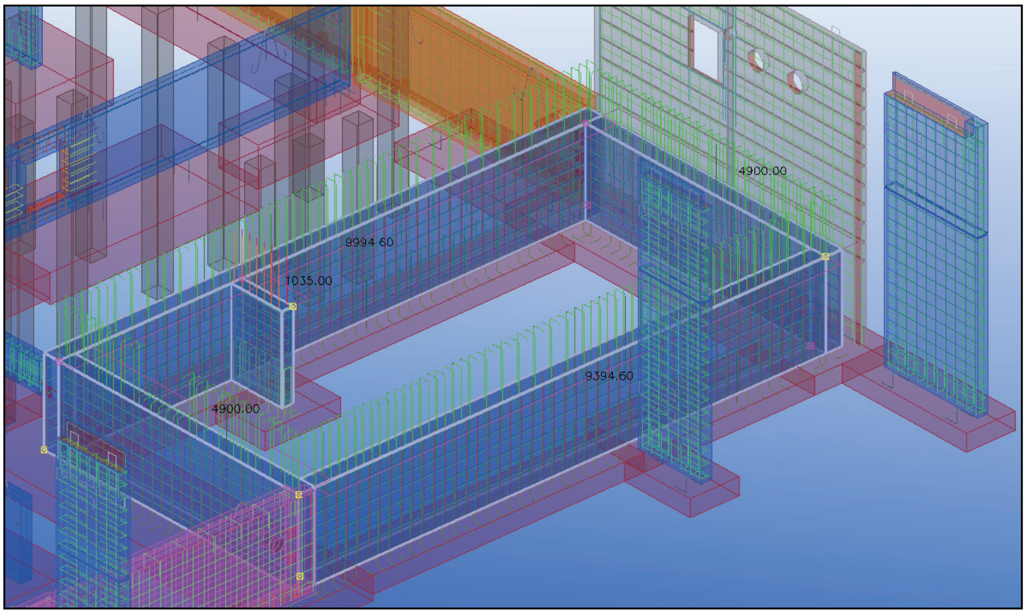


Figure 31. The civil defense shelter products are selected for detailed cost estimation

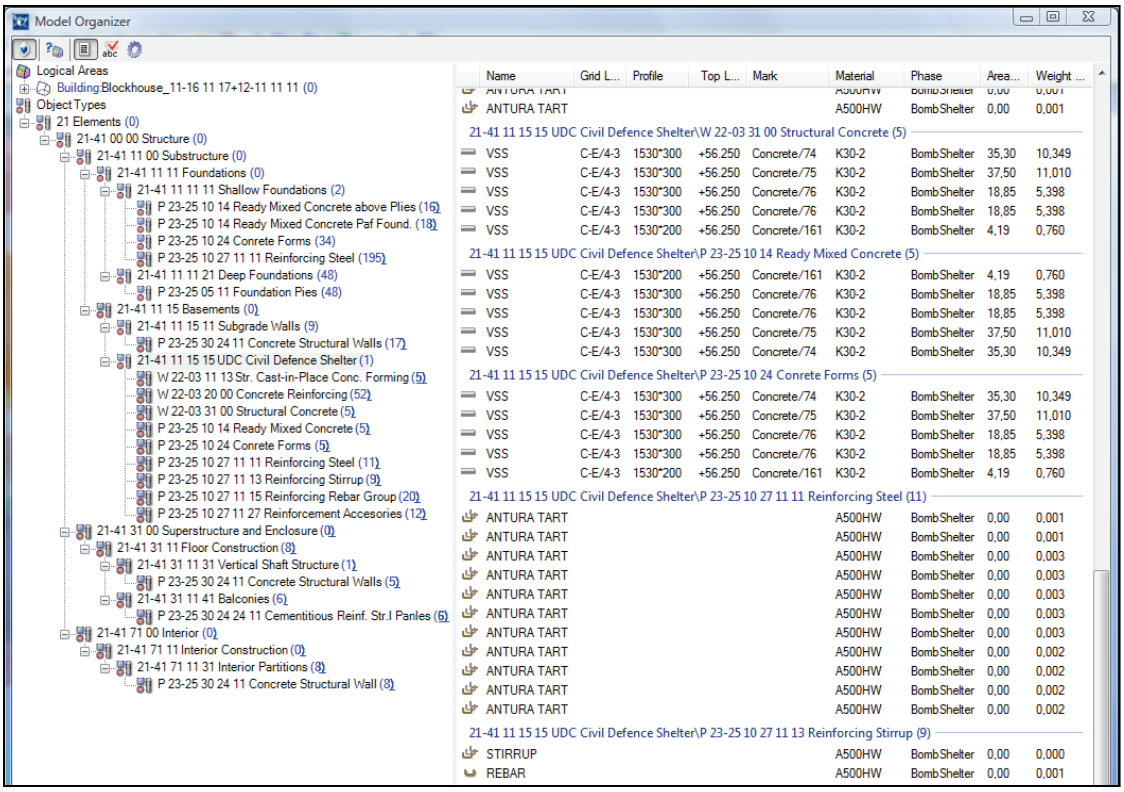


Figure 32. Inquire of product and work results in the civil defense shelter for detailed cost estimation

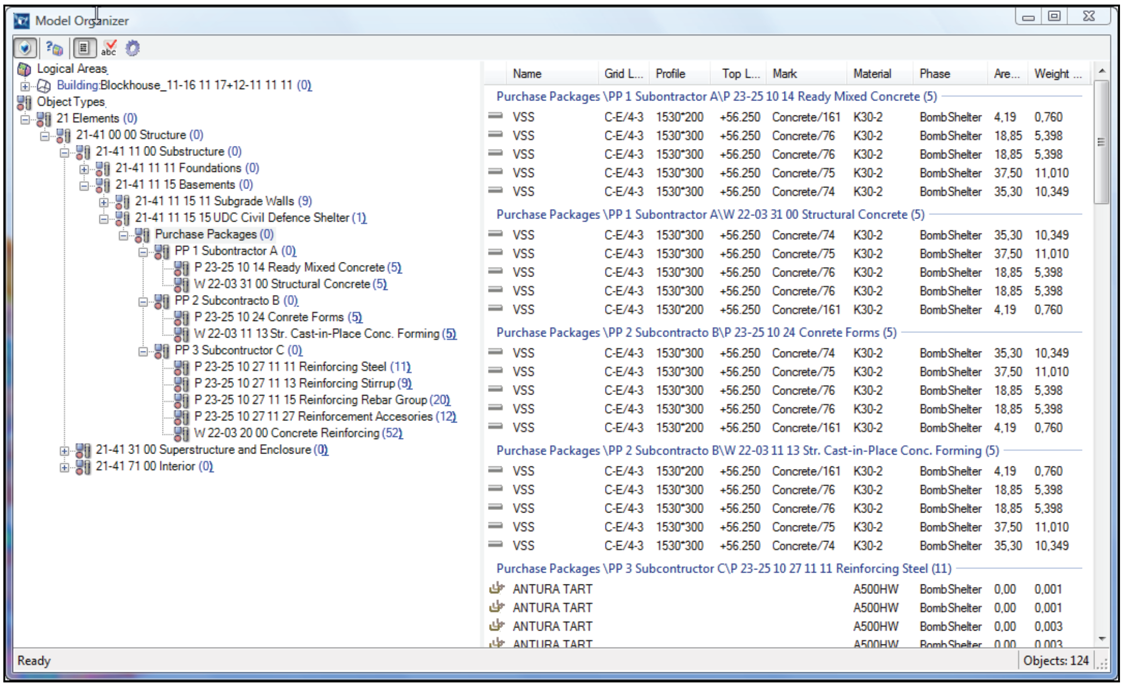


Figure 33. Purchase packages of civil defense shelter in Model Organizer

6.4 Precast Concrete Production with the Tekla Structures and Model Organizer

The precast concrete elements have all the necessary data for the production in the Tekla Structures. The data transfer from the Tekla Structures to production software for example to Eliplan is already working in real practice.

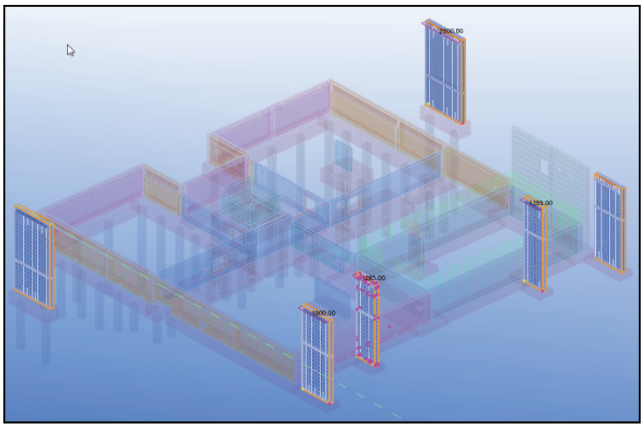


Figure 34. Balcony elements are selected

In Figure 34 the balcony elements are selected from the model for preparation for production.

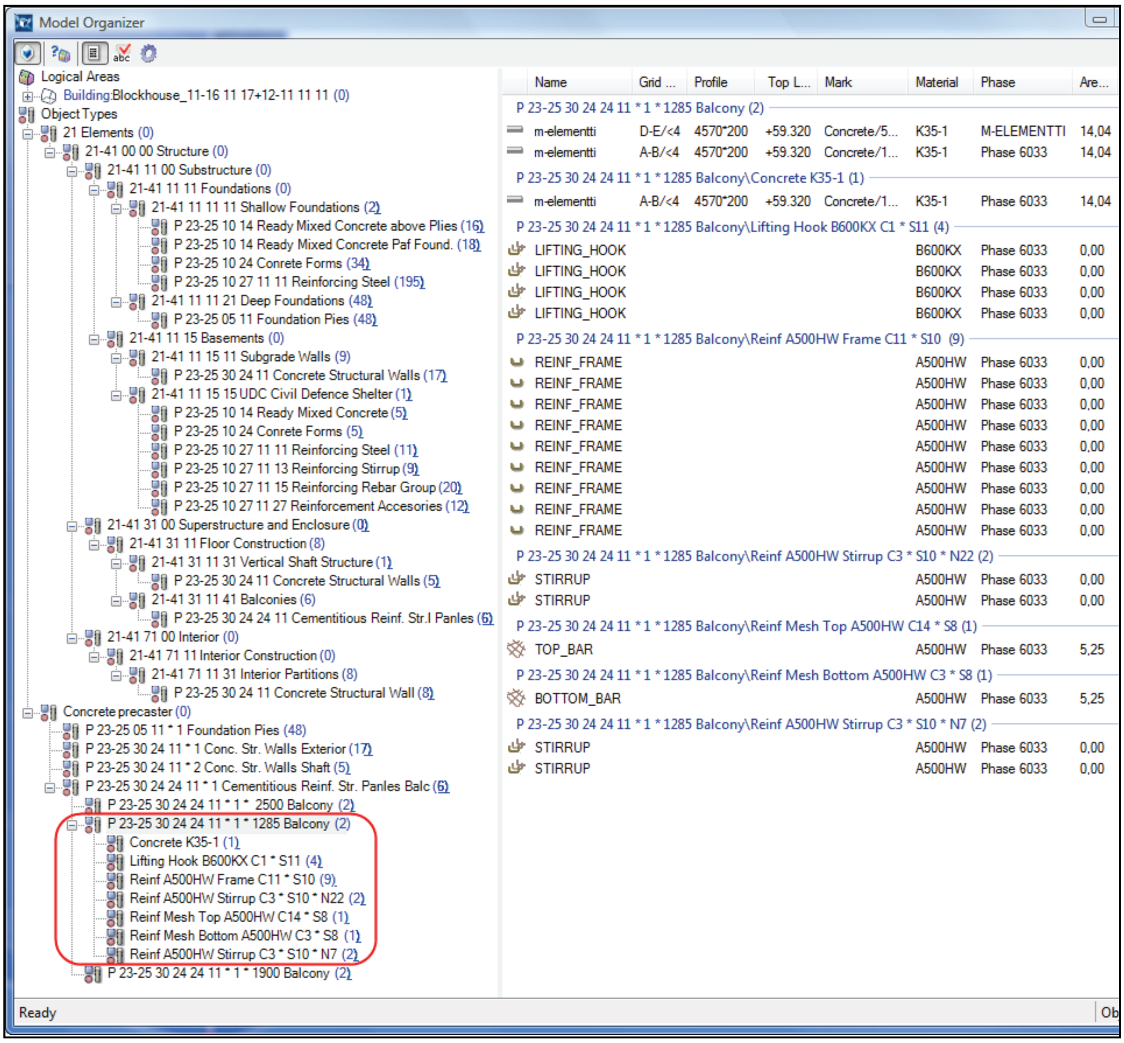


Figure 35. Detailed product inquire of selected balcony elements in Model Organizer

In the future the construction project manager or the precaster can categories the precast concrete elements in the model by collecting them under e.g. the precaster company name, and giving extension to the classification code. On Figure 35 the precast products are collected under the category “Concrete precaster”. The vertical balcony elements are further detailed. The three different sizes got different product names, like [P 23-25 30 24 24 11 * 1 * 2500], [P 23-25 30 24 24 11 * 1 * 1285] and [P 23-25 30 24 24 11 * 1 * 1900]. [23-25 30 24 24 11] is the OmniClass code of the Cementations Reinforced Structural Panels. [* 1] is the code for vertical balcony elements within the precast company, [2500, 1285 and 1900] are the width of the different elements. The code can be extended as far as the production and shipping needs it. The products in the element are coded for example as [Reinf A500HW Stirrup C3 * S10 * N22] where [C3] refers to Class 3, [S10] refers to Size 10 and [N22] refers to the number of stirrups in the group.

Figure 36 shows an example to property settings of reinforcement meshes in the Tekla Structures. The meshes were created as components (Slab bars (18)) in the Tekla Structures and the inserted data is sufficient for the production of the mesh.

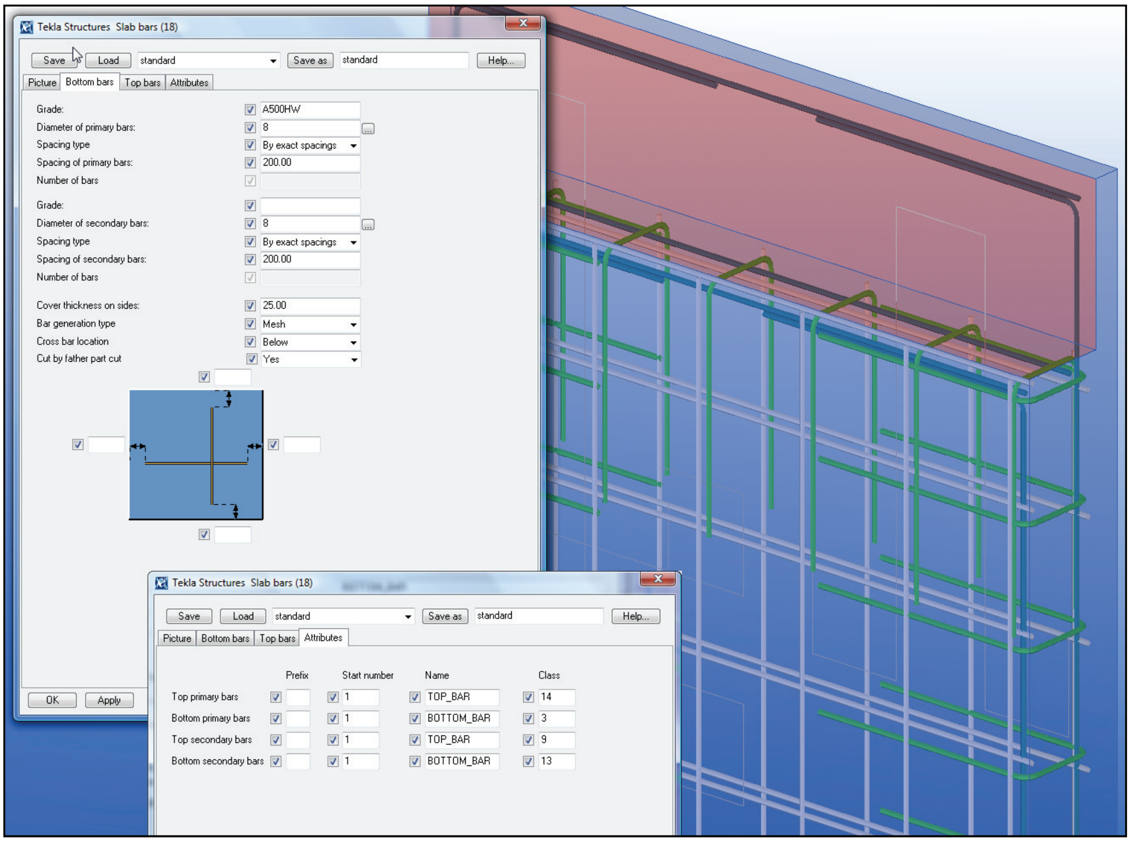


Figure 36. Information about the reinforcement mesh in a balcony element

7. SUMMARY

7.1 Introduction

The concept of Building Information Modeling (BIM) will change and make more effective the processes in the construction industry in the near future. The newest configuration of the model-based software product the Tekla Structures is serving the construction management and the task management at the site. Further improvement of the software is necessary for utilizing the inherent possibilities and this way simplifying construction related processes. Tekla has realized a new direction of development, which is searching for possible links between the structural model, the task management and the building classification systems. This issue was researched by the author in cooperation with Tekla and the International Construction Business unit (HUT/ICB) at the Helsinki University of Technology in a form of master's theses in ICB. As an intermediate result of this research a conference paper was published on the conference CIB IDS 2009, with the same title as the present thesis. The authors of the paper were Jukka Suomi from Tekla Corporation, Matti Tauriainen from HUT/ICB and the author. As an empirical approach, interviews were performed with experts and construction companies from Finland, and literature review was carried out in the topic. The results were tested by performing the classification on a real structural model and making inquiries from it. This can be considered as "vertical" approach. The "horizontal" cross section of the problem is the viewpoint of a single element, namely how the information is attached and retrieved from the element during the construction process. The present study does not give a software design solution, but provides the theoretical base for an information delivery manual utilizing the new software solutions' capabilities. The direct and indirect classification methods are discussed and compared in the study, taken into account the complexity of the built environment.

7.2 Theoretical bases

As a foundation of the study three generic concepts and a novel theory of classification methods in CAD software were used.

The Finnish contractual arrangements are taken as example in this study. The three main contractual arrangements in Finland are: the general contract, the simple split contract and the design and build contract. There are many variations of these according to the pricing method. This study utilizes two construction process diagrams from different backgrounds. One is a Finnish 'construction management company' specific diagram. The other diagram is a recommendation created by scientists, and it narrows down the scope to the precast concrete industry in the USA.

Classification is an abstraction mechanism by which component classes can be arranged in a hierarchy, termed taxonomy. The most general classes are at the higher level and the most special classes are at the lower levels. The use of classification systems has been fragmented until recent times, and mostly limited to the use for cost calculations by construction companies. The International Organization for Standardization (ISO) 12006-2 Organization of Information about Construction Works – Part 2: Framework for Classification of Information has come into being in year

2001, which attempts to cover all the possible perspectives of the construction lifecycle.

Cost modeling is a process that attempts to bring design and price together. It has the objective of controlling costs, not just to measure them. Cost modeling therefore is defined to be the assessment and control of cost prior to the availability of knowledge of the element content of a project. Cost modeling is undertaken progressively throughout the design and construction of a project and makes use of the information that is available at the time.

7.3 Classification systems in Finland and internationally

The basis of a successful information transfer is an analysis of the construction process and a classification based on the findings. During the process, it is necessary to see the building itself and the activities linked to its production from many different points of view, each of them having its specific use and user group.

The extent of application of classification systems differs greatly in different countries. International standards are created to support these efforts between and within different countries. National classification systems have been changed and others could be changed to follow the directions of the international standard, ISO 12006-2. The common understanding of classification systems will help also in international operations.

The come into being and the current role of CSI (Standards & Formats, Professional Development and Certification) in the USA, the OmniClass classification system, the IFD (International Framework for Dictionaries) and IFC (Industry Foundation Class) is discussed.

OmniClass is a standard for organizing all construction information. The concept has been developed by the International Construction Information Society (ICIS).

MasterFormat 2004 Edition (MF04) was published by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC) in the fall of 2004. The new 50-Division organizational structure replaced the 16-Division structure that dates back to 1964. MasterFormat has become a USA and Canadian standard classification system for written construction documentation. MasterFormat is used to classify construction cost estimate information for construction documents preparation and tendering. A new classification system has been introduced for estimating anticipated construction costs during early design stages. This system is called UniFormat and is a “building elements” based system. By using a relational database approach, Building Systems Design, Inc. automated the transition from MF95 to MF04 by adding new fields for the 2004 numbers and titles, mapping the old numbers and titles against the new ones.

The most common construction contract in the USA is the single contract, the multiple prime contracts form, than the construction management and design-build contracting in the order of the listing.

In Finland there is a long history of applying national construction classification systems like Building 70, Building 80, Building 90 and Building 2000. Building 90 and Building 2000 include a complete set of classification tables for spaces, building elements, work sections and different resources as construction products, labor and site equipment The Finnish classification systems specify a series of classification tables and they state a method for cost estimation. The Finnish National Specification System: 'RYL' consists of two main document groups: project specification writing guides and reference specifications. The specifiers (normally the architects) use the 'Specification Writer's Guide', which contains a complete list of building element items arranged according to Building 90 codes.

The main difference between the mostly used North American classification system MasterFormat 1995, 2004 and the Finnish Building 70 – 2000 is that the American ones are based on Work Results, while the Finnish ones are based on the Elements. One can recognize a strong similarity in the transition process of the Finnish and the USA classification system shift in the construction industry.

Based on the interviews there is no need for very detailed base classification system, because the constructor and subcontractor companies' organizational structure and working practices widely differ. They see the adequately refined classification system as their competitive advantage. They can further refine the national classification system and still they can communicate to other companies through the base classification system or through the commonly agreed refined classification system.

7.4 Use of the Tekla Structures in different construction processes

In this chapter the users of the 4D the Tekla Structures model are drawn up by analyzing two process diagrams in the construction industry from two countries A Finnish project management process diagram and USA precast concrete process diagram is studied.

The identification of current users of the Tekla Structures in Finland, the piloting users, and the users predicted in middle run and in long run are presented. The construction industry players, the client or developer, the user or facility manager, the architect, the structural engineer, the mechanical engineer, the contractor and the subcontractor are the potential users of the Tekla Structures. Currently there are certain companies in all the seven identified construction industry players which are using the Tekla Structures to some extent. The current situation of the Tekla Structures use and the predicted later use within the BIM concept is detailed.

The precast concrete production process in the USA is studied as an international comparison base. The examined process diagram is taken from the "Information Delivery Manual for Precast Concrete" prepared about the USA precast concrete industry. From Tekla point of view, the precaster as subcontractor project and as the continuation, the Fabrication and erection process was studied. The following disciplines of the construction process are identified: architecture, engineering, building product manufacturing, general contracting and plant management. The phases of the projects are: preliminary project description, design development, construction documentations, procurement, product development, fabrication and erection phase. There are significant discrepancies among models with regard to the amount of detailed design performed prior to award of contract. In all cases, the precast producer must estimate the variety and quantity of pieces that will be required. The detailed description of the Tekla Structures users is given in the precast concrete production process in the USA.

Although precast concrete offers significant potential advantages in quality, speed of erection, and cost, its share of the overall building construction market in North America is very low especially when compared with other industrialized regions in European countries. In the USA communication of engineering data remains almost entirely 2D or paper based in all of the companies.

7.5 Classification information in the Tekla Structures Model Organizer

The theory of linking objects to classification systems is presented. The automation of the direct linking of the 3D model to the classification brings a great benefit to the creators and users of classification information. There are two principal methods for connecting classification information to model objects. Direct classification method: the classification information is stored as an attribute to each object. Indirect classification method: the model objects and classes are connected to each other with a dependency. Attributes and the way of linking it to the objects can be divided to two main categories: Geometrical attributes are created to define the geometrical appearance of the object. Non-geometrical attributes are additional information tagged to the objects. With the indirect classification method objects are automatically linked to classes and automatically switched to the correct class when changes occur in the model. Objects belong to as many classes as needed. In practice automation seldom provides a 100 percent precise classification result as there is a great variation of needs, therefore the semi-automated method is suggested. Satisfactory classification functionality is reached by the combination of automatic indirect classification and the possibility of manual adjustment.

The use of classification information can be broadened from cost estimation to assist throughout the whole construction process, because different classification codes can be formed and stored within the Tekla Structures Model Organizer, attached to the model. The strategy for new processes in the construction industry, related to the Tekla Structures Model Organizer is formed based on the following sources: identification of the Tekla users in Finland and Tekla users in USA (Ch. 4) and the interviewees view on the present situation of the industry (Ch.6.1). The application of classification systems in the Model Organizer is the most recommended way of working with this tool. The national or international classification systems are based on common scientific agreement, and could serve well as the base classification system for the operations.

The Tekla Structures Model Organizer can store predefined classification groups, but the user is free to create any number of new groups that the project requires. The model objects are filtered and linked to the corresponding classes in the Model Organizer.

The predefined part of the classification system is the base classification system in the Model Organizer. Structural engineers and architects deal with the predefined part. The dynamic part is the further refined classification system serving the needs of the contractor, subcontractors and other users of the 4D model. There is a possibility to agree on specific use of the classification system, and on the method of extending or refining it project by project. Contractual forms must reflect these project needs. Actions are recommended to the industry players in the study, supporting the information flow in the construction industry.

The compatibility of construction-related information is increased when working on common ground within the classification systems. One of the greatest benefits of the suggested working method is that the changes in the plan are more easily handled with the use of BIM and the common classification system. Construction time can be reduced, costs can be reduced; therefore owners and developers can gain competitive advantage and give their organizations a better return on their capital investments.

7.6 Empirical testing

The interview questions were created by the author. The questions were divided to 3 groups concentrating on the experience of the interviewee and his/her employee regarding the classification systems, the software used in this field at the company in question, and the development of the classification system in use in a line with the construction process development efforts in the interviewee's company.

The interviewees generally agreed on that with old types of regular projects the use of Building 80 is satisfactory, but the modeling based processes require new classification system, like Building 2000. The introduction of new software can be the force for changing and developing of processes. All the interviewees agreed that there is great need putting more effort into the construction process development, because a lot of time and money is wasted on the repeated manual data input, and information brakes. One suggestion was for industry level development that regular communication should be established between the subcontractor / supplier and the designer. Feedback is needed related to the products used, and the classification numbers of those products. The result of the interviews is concluded about the classification systems, the software used and the information flow in the construction industry in Finland in the present time.

A partly already implemented and partly imaginary information flow is presented in this section throughout the whole construction process. It is pointed out where the information about the building element enters the Tekla Structures, and how Model Organizer can help in keeping the information up to date and easily reachable.

The support for quantity takeoff and cost estimation is studied. Two stages of the cost estimation process are taken as example: the approximate estimate stage and the detailed estimate stage.

Filtering and reporting the information based on the purchase package groups in Model Organizer helps creating exact tendering packages for subcontractors.

The precast concrete elements have all the necessary data for the production in the Tekla Structures. In the future the construction project manager or the precaster can categorize the precast concrete elements in the model by collecting them under e.g. the precaster company name, and giving extension to the classification code.

There is an ongoing project in Tekla for the renewing of Model Organizer and finding the optimal links between Model Organizer and other applications in the Tekla Structures. The report creation from Model Organizer is possible through the Tekla Structures report templates or to excel tables, and also the information displayed by Model Organizer will be printable in the upcoming versions of the Tekla Structures.

8. CRITIQUES OF THE STUDY AND RECOMMENDATIONS

8.1 Critique of the study

Literature review was partly based on books, but mostly on materials retrieved from the internet. The real internationalization of the construction classification systems is still waiting to be implemented; therefore the available material about the internationalization mostly covers the scientific research results and describes the efforts taken forward the implementation. The available material about the Finnish classification systems is limited in English, but the basic information was reachable.

The concepts which are giving the base of this study are very general therefore there are many different descriptions available about them. The chosen definitions are country specific in many cases; however it is explanatory having the definitions accompanied by its applications.

As a critique of the study it is noted that the study describes only a part of the construction industry in Finland through the means of working and information exchange methods. In the opinion of the author in the long run, as the technology develops, the classification systems will change its form and meaning. The present description of application is a step towards a more generally applicable solution. Therefore the presented approach can be considered as a temporary way of working to enhance the cooperation between construction industry players.

There were no interviews made with companies located in the USA due to the geographical distances. Only the precast concrete industry was covered in the USA, based on a theoretical information flow. In reality the processes are much more difficult to follow up.

8.2 Recommendations to practitioners

In Finland the Building 2000 classification system should be put into use in the near future in order to reach synergy form the classification system use. To support the change, example can be taken from the USA institutes supporting the change by automating the transition from MF95 to MF04.

The construction industry as a whole is changing very slowly. To fasten the changes towards the BIM solutions the owners and developers need to be more aware of the importance of their requirements towards the architects, engineers and contractors. On the other hand all the parties of the industry must realize the benefits of the BIM solutions. These benefits can come into being only by careful planning of the construction related processes and eliminating all the unnecessary loops and information flow brakes. This study and the related conference paper hopefully provides a base for further thinking and discussion of the issue and more and more companies are going to reconsider their processes when taking into use the available IT solutions and implementing the real BIM.

National research institutes could create information delivery manuals about different contracting methods as templates to be customized and implemented by the industry.

The “Information Delivery Manual for Precast Concrete” can be a good base to the research of this direction.

The practice of classification in other industries could be investigated. Probably there are many similar challenges, and good solutions could be implemented in the construction industry also.

8.3 Recommendations to the Tekla Structures developers

To take advantage of the changes of present time, Tekla needs to have close relationship with those companies which are committed to the changes and are eager to pilot the new solutions, as it is already an implemented good practice. However Tekla could be more influential if the software development could go before the demand appears on the market. To achieve this goal, more investment is needed in the research of this field. New theories are available on the scientific field waiting for implementation, so Tekla needs to make efforts to collect the up to date scientific results, and study the viability and applicability of them.

One possible development path is to research the space based classification systems. The Tekla Structures can already import spaces from an architectural model. It could be studied how the space structure can be the base of the classification system in Model Organizer, and how the building elements can be linked to these spaces.

Tekla could be proactive providing new process solutions to the construction management. For example Tekla could publish examples of country or area specific construction management procedures on its website or on the Extranet. Also edited basic versions of the different classification systems could be made available on the Tekla Structures Extranet. The user could download and insert the classification system file into the Tekla Structures version he uses.

For comprehensive handling of Model Organizer, Task Manager, others tools, new types of links could be implemented between the different tools in the Tekla Structures. For example the Task Manager tasks could have direct link to the Model Organizer ‘work results’ section. Other resources, like the equipments used during the construction also need to be considered. The Task Manager and/or the Model Organizer could contain categories for the equipment use and space use.

In the opinion of the author the Model Organizer needs to be available in all the Tekla Structures configurations in order to implement the solutions presented in this study.

The report creation from Model Organizer is possible through the Tekla Structures report templates, however this function has limitations at this moment. The report creation from Model Organizer needs to be further developed to enable the quantity takeoff for detailed cost estimation purposes. The desired end result is a report similar to the structure of information displayed in the Model Organizer.

It would be beneficial further studying the differences between the element based and activity/work result based classification systems. Can they fully substitute each other? Using a work result based classification system would ease the linking of the Model Organizer classification groups and the tasks in Task Manager.

LIST OF REFERENCES

Building 90 Group and The Finnish Building Centre Ltd. 1999. Building 90. The Finnish Building Centre Limited, Helsinki (Rakennustieto Oy, Helsinki) ISBN 951-682-580-X

CSI The Construction Specifications Institute. 2003. About CSI. [Online]. Accessed 20.3.2010 at: http://www.csinet.org/Functional-Menu-Category/About-CSI.aspx

CSI Construction Specification Institute. 2009. About IFD. [Online]. [Cited 20.3.2010]. Available at: http://www.csinet.org/s_csi/sec.asp?CID=2446&DID=15842

Colin, D, McGregor. 2001. A Description and Comparison of National Specification Systems, Report No. 1, International Construction Information Society. [Online]. [Cited 5.2.2009]. Available at: http://www.icis.org/index.php?page=rtdocs/index.php

Eastman, C. & Teicholz, P. & Sacks, R. & Liston, K. 2008. BIM Handbook, A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors. USA, Wiley & Sons, Inc. 2008. ISBN 978-0-470-18528-5 (cloth)

Facilities Information Council. 2007. United States National Building Information Modeling Standard, Version 1- Part 1,Overview, Principles, and Methodologies. [Online]. National Institute of Building Scienses. [Cited 20.3.2010]. Available at: http://www.wbdg.org/bim/nbims.php

Gulledge, C. E. & Beougher, L. J. & King, M. J. & Dean, R. P. & Hall, D. J. & Giglio, N. M. & Bevier, G. W. & Steinberg, P. 2007. MasterFormat™ 2004 Edition 2007 Implementation Assessment. [Online]. The Construction Specifications Institute. [Cited 15. 3. 2010] Available at: http://www.csinet.org/s_csi/docs/14900/14844.pdf

ISO/FDIS 12006-2. 2001. International Standard, Building construction- Organization of information about construction works- Part 2: Framework for classification of information. Reference number ISO/FDIS 12006-2:2001(E)

Johnson, R. W. Chair & UniFormat Task Team. 2008. Introduction- Draft for Public Review and Comment- March 31, 2008, Commentary on Proposed Revisions to UniFormat. [Online]. [Cited 3.4.2009]. Available at: http://www.csinet.org/s_csi/sec.asp?CID=1377&DID=11705

Jørgensen, K. A. 2010. Classification of building element functions. In: Dikbas, A.& Ergen, E.& Giritli, H. (editors) Managing IT in Construction/ Managing Construction for Tomorrow. Istanbul, Turkey 1 and 3 October 2009. The Netherlands: International Conference on Managing Construction for tomorrow (MC4T) and the CIB W078 Conference on Managing IT in Construction. p 301- 307. ISBN 978-0-415-56744-2 (hbk), ISBN 978-0-203-85978-0 (eBook)

Kiiras, J. & Kruus, M. & Hämäläinen, A. & Lindroos, H. & Saari, A. & Salmikivi, T. 2007. SUKE Malli talotekniikan suunnittelun ja hankintojen ohjaukseen projektinjohtohankkeissa, Rakennustieto Oy. Helsinki. 64 p. ISBN 978-951-682-877-3

Knopp-Trendafilova, A. & Suomi, J. & Tauriainen, M. 2009. Link Between A Structural Model Of Buildings And Classification Systems In Construction. In: Belloni, K. & Kojima, J. First International Conference on Improving Construction and Use through Integrated Design Solutions People – Technology – Processes. Espoo, Finland 10-12 June 2009. Espoo, Finland: Finnish Association of Civil Engineers RIL, VTT Technical Research Centre of Finland, International Council for Research and Innovation in Building and Construction CIB. P. 226-239. ISBN 978-951-758-506-4, ISSN 0356-9403

Kohvakka, A. 2006. Senate Properties. [Online]. [Cited 4.3.2009] Available at: http://www.senaatti.fi/document.asp?siteID=2&docID=517

Palos, S. 2010. Tietomalliprosessi – tietomallitiedon käyttö suunnittelussa, rakentamisessa ja ylläpidossa. Master's thesis. TUT, Tampere University of Technology, School of Architecture. Tampere

LaNier, M. & Eastman, C. & Sacks, R. & Panushev, I. & Aram, S. & Yagmur, E. 2009. Information Delivery Manual for Precast Concrete. The National Building Information Modeling Standards. The Charles Pankow Foundation, the Precast/Prestressed Concrete Institute (PCI)

McGraw Hill Construction Sweets Network Master Format. 2004. 22 00 00 Plumbing. [Online]. [Cited 10.2.2009]. Accessed at: http://products.construction.com/BrowseByDivision

Mehus, J.& Grant, R. 2009. IFD Library Business Plan Version 1.0. [Online]. Developed and reviewed by IFD Library Business Management Group. Prepared by Roger (CSI) and Jacob (Standards Norway) [Cited 6.7.2009]. Available at: http://www.ifd-library.org/

Mindt, B. 1995. Trends and Perspectives of National Specification Systems in European Construction, Report No. 2, International Construction Information Society [Online]. [Cited 5.2.2009]. Available at: http://www.icis.org/index.php?page=rtdocs/index.php

OmniClass Secreteriat. 2006. OmniClass™ A Strategy for Classifying the Built Environment, Introduction and Use’s Guide Edition 1.0, 2006-03-28 Release. [Online]. [Cited 4.5.2009]. Available at: http://www.omniclass.org/

Sacks, R. & Eastman, C. M. & Lee, G. 2004. Process Model Perspectives on Management and Engineering Procedures in the Precast/Prestressed Concrete Industry. Journal of Construction Engineering and Management. ASCE/ march/April 2004. DOI: 10.1061/(ASCE)0733-9364(2004)130:2(206)

Wix, J. 2005. Cost Modelling, IFC 2x2 Addendum 1. [Online]. National Institute of Building Sciences, Facilities Information Council, National BIM Standard. [Cited 20.3.2010]. Available at: ftp://ftp.iai.no/pub/idm/process_maps/

APPENDICES

APPENDIX 1. INTEVIEW QUESTIONS

Questioner

1. Name
2. Company
3. Position
4. Previous positions and companies relevant in the interview

Classification systems:

5. Which classification systems have you used already? (Construction related or other.)
6. Does your company have its own classification system?
7. If yes? What do you use it for? Do you shear it with business partners?
8. Which level of classification do you use? Element, product, work results?

Software:

9. Which software have you used so far related to classification systems?
10. Which software have you used so far for your production and interoperations with other companies?

Development of utilizing classification systems

11. How do you see: are the present classification systems serve your goals effectively?
12. What kind of change would you like to have?
13. Do you see a need for putting more effort to develop the information flow between the construction industry parties?
14. Where does the information flow brake in the construction process? How do you deal with it? (Manual data input…)
15. What do you expect from Tekla in terms of utilizing classification systems?
16. How do you see the industrial impact of the new solution?

APPENDIX 2. DESCRIPTION OF TERMS IN THE THESIS

Acronym/Term	In full	Description
General		
BARBi	Bygg og Anlegg Referanse Bibliotek	The original Norwegian development which is part of IFD Library
IFD	International Framework for Dictionaries	Initiative to build a construction wide object library based on the principles of ISO 12006-3:2007
IFD Concept		The IFD Concept is the building block of IFD Library. A concept is a thing that can be distinguished from other things and recognized as such, and is represented by a name (term). In IFD Library a concept is described both by a set of names and definitions in multiple languages but also with relating a concept to other concepts.
IFD Context		A context in IFD Library is a grouping of relationships that exists between concepts. There are multiple ways of viewing a concept and the relationships between concepts. IFD Context is the filtering mechanism used organize these views.
IFDL	IFD Library	An object-oriented database of concepts which we can use to describe the built environment. A component of the buildingSMART technology http://www.ifd-library.org
IFDLG	IFD Library Group	The group of participating organizations in building IFD Library. See IFD Library Group Charter in Appendix C
IFDLG-BMG	Business Management Group	The BMG is made up of representatives of the IFD Library Group Partners. See IFD Library Group Charter in Appendix C
IFDLG-TG	Technical Group	The TG is also made up of Partner representatives as well as representatives from organizations conducting projects using IFD Library. See IFD Library Group Charter in Appendix C
IFDLP	IFD Library Partners	See IFD Library Group Charter in Appendix C
IFD Library Affiliates		Organization which has been approved by the IFD Partners to execute a project to extend or enrich the IFD and signs a project agreement. See IFD Library Group Charter in Appendix C
IFD Library Observers		Organization which has expressed an interest in the IFD and signs and LOI. May become Partner in future but not automatic. See IFD Library Group Charter in Appendix C
IFD Library Partners (IFDLP)		The organizations working together on the development of IFD Library and members of the Business Management Group. See IFD Library Group Charter in Appendix C
LexiCon		The original Dutch development which is part of IFD Library

Acronym/Term	In full	Description
Organization(s)		
bSN	buildingSMART Norway (NO)	http://www.buildingsmart.no/
buildingSMART International		buildingSMART International (formerly IAI International) http://www.buildingsmart.com is an international membership organization with representation in North America, Europe, Asia and Australasia. IFD Library Group is a part of buildingSMART International
buildingSMART IC	buildingSMART International Council	The highest decision making body within the buildingSMART International.
buildingSMART ITM	International Technical Management Committee	The International Technical Management Committee is the highest level technical decision-making and technical project management body for buildingSMART International.
buildingSMART MSG	Modeling Support Group	Model Support Group (MSG) is a standing group under ITM. MSG members are modeling specialists selected for their proven skills. Their primary role is the quality assurance, integration and maintenance of the IFC model and its documentation.
CSC	Construction Specifications Canada (CA)	http://www.csc-dcc.ca/ IFD Library Group Partner
CSI	Construction Specifications Institute (USA)	http://www.csinet.org IFD Library Group Partner
EPM Technology		Developer of model servers, currently hosting IFD Library database. www.epmtech.jotne.com/
FIATECH		FIATECH provides global leadership in identifying and accelerating the development, demonstration and deployment of fully integrated and automated technologies to deliver the highest business value throughout the life cycle of all types of capital projects.
Holte Byggsafe		Developer of the IFD Library Propertylizer and IFD Library .NET toolkit.
ICC	International Code Council	US organization that administers the International Building Code (IBC) and developer of SmartCodes
ICIS	International Construction Information Society	ICIS is a worldwide association of organizations which provide national master specification systems and/or cost information systems for the construction industry.
NOBB	Norsk Byggevarebase	Norwegian system for product information
SINTEF Building and Infrastructure		Norwegian research institute heavily involved in the development of the IFD Library Technical Infrastructure www.sintef.no/Home/Building-and-Infrastructure/
STABU Foundation	Dutch Specification Institute (NL)	http://www.stabu.org IFD Library Group Partner

Acronym/Term	In full	Description
Technical		
IFD Library API	Application Programmers Interface	The way to access the IFD Library through a web service. Full documentation on http://dev.ifd-library.org
BIM	Building Information Modeling	The process of developing a virtual representation of a real building. Beyond geometric data, BIM includes all types of information about a facility.
CITI	Construction Industry Terminology Initiative	CSI program for identifying term used in drawings and specifications
EULA	End User License Agreement	
GUID	Globally Unique ID	Identifier for an item that is guaranteed to be unique everywhere. A pseudo-random number used in software and database applications. While each generated GUID is not guaranteed to be unique, the total number of unique keys (2128 or 3.40282366×1038) is so large that the probability of the same number being generated twice is very small. The term GUID usually references Microsoft's implementation of the Universally Unique Identifier (UUID) standard, however, many other software developments and standards including IFC use the term GUID.
Pset tool	Propertyset tool	Connection tool between IFC and IFD. Managed by buildingSMART MSG
SDK	Software Developers Kit	Set of programming tools that allow programmers to develop specialized computer applications and adapt them to various operating systems
UI	User Interface	

Acronym/Term	In full	Description
Classifications/Standards		
EPISTLE	European Process Industries STEP Technical Liaison Executive	
ETIM	Electronical system Installation techniques	Article classification for Electrical articles. Developed in The Netherlands, now being implemented in multiple European countries.
EXPRESS		A data definition language defined by ISO 10303-11 EXPRESS language reference manual. EXPRESS is a formal language that can be used to define product data models. Note: IFC Object Model is defined using the EXPRESS language.
EXPRESS Model		An information model described using the EXPRESS language. An EXPRESS model may comprise a number of interrelated schemas.
EXPRESS-G		A graphical notation for the EXPRESS language. EXPRESS-G defines graphical symbols for a subset of the elements of the EXPRESS language.
EXPRESS-X		A mapping specification language for defining a mapping between data sets based on different EXPRESS-models.

		EXPRESS-X is defined by ISO 10303-14 within the EXPRESS language family.
IDM	Information Delivery Manual	A standard, ISO DIS 29481-1 under development of ISO/TC 59/SC 13, which enables building processes to be modeled; enables delivery of relevant model data to the appropriate user. According ISO DIS 29481-1 The IDM specifies: ▪ a methodology that unites the flow of construction processes with the specification of information that is required by this flow, ▪ a form in which the information should be specified, ▪ an appropriate way to map and describe the information processes within a construction lifecycle.
IFC	Industry Foundation Classes	An international specification for product data exchange and sharing for AEC/FM. IFC enables interoperability between the computer applications for AEC/FM. A subset of IFC is approved as ISO/PAS 16739.
ISO 10303 Standard		ISO 10303 Product data representation and exchange standard. An international standard that has defined the basis for product data technologies, and product data exchange standards for a number of industry sectors.
ISO 12006-3	Framework for Object Oriented Information Exchange	This part of ISO 12006 specifies a language-independent information model which may be used for the development of vocabularies used in information about construction works. It enables classification systems, information models, object models and process models to be referenced from within a common framework.
ISO 15926	Methodology for the creation of reference data libraries	Industrial automation systems and integration - Integration of life-cycle data for process plants including oil and gas production facilities
MVD	Model View Definition	Model View Definitions (MVD) are used for documenting IFC based data exchange capabilities in software. www.blis-project.org/IAI-MVD
OmniClass		North American classification System for the construction industry developed according to ISO 12006-2. www.omniclass.org
SfB	Samarbetskommitten for Byggnadsfragor	The original SfB system was developed in Sweden in 1959. Still used widely in construction industry in multiple countries. Available in multiple languages.
STEP	Standard for The Exchange of Product model Data.	A set of international standards under the designation ISO 10303.
Uniclass	Unified Classification for the Construction Industry	British classification system for construction industry published in 1997 in UK by the Construction Project Information Committee (CPIC). www.en.wikipedia.org/wiki/UniClass

(IFD, 2009)

APPENDIX 3. BUILDING 2000 CLASSIFICATION SYSTEM

Building 2000 classification system consists of six classification tables. The tables and the main contents of tables are listed below:

Premise and Space Classification table (Tilanimikkeistö)
A Residential Premises
B Free Time Residential Premises
C Commercial Premises
D Office Premises
E Transport and Communication Premises
F Premises of Institutional Care
G Assembly Premises
H Educational Premises
J Industrial Premises
K Warehouses
L Defence, Rescue and Fire Fighting Premises
M Agricultural Premises
N Other Premises
1 Dwelling Spaces
2 Administration and Business Spaces
3 Education and Research Spaces
4 Other Premises-specific Spaces
5 Storage spaces
6 Culinary Spaces
7 Staff Facility Spaces
8 Common Spaces
9 Communications and Technical Service

Building Element and Project Classification table (Hankenimikkeistö)
1 Construction Elements
2 Services Elements
3 Project Administrations
4 Real Property Duties
5 User Duties
6 Project Stipulations

Construction Work Section Classification table (Tuotantonimikkeistö)
1 Demolition and Renovation Work
2 Site Substructure Work (Substructure Earthwork)
3 Site Superstructure Work (Superstructure Earthwork)
4 Concrete Works

5 Masonry Work
6 Metal Works
7 Carpentry Work
8 Glass Work
9 Insulation and Proofing Work
10 Surface Finishing Work
11 Fixtures and Fittings Work

Construction Product Classification table (Tuotenimikkeistö)
1 Site and Earth Work products
2 General Products (Sub- and Superstructure Products)
3 Structure Completing Products
4 Finishing Products
5 Building Fixtures and Fittings
6 Mechanical and Electric Installations Products
7 Worksite Equipment
8 Operational Devices

Worksite Equipment Classification table (Kalustonimikkeistö)
0 Demolition Work Equipment
1 Earthwork Equipment
2 Concrete Work Equipment
3 Masonry Work Equipment
4 Metal Work Equipment
5 Woodwork Equipment
6 Insulation and Proofing Work Equipment
7 Surface Finishing Work Equipment
8 Fixtures and Fittings Work Equipment
9 General Site Equipment

Building Resources Classification (Panosnimikkeistö)
1 Labour Resource
2 Product Resources
3 Subcontract Resources
4 Equipment Resources
5 Company Activities

APPENDIX 4. CONTENT OF THE FINNISH SPECIFICATION SYSTEM

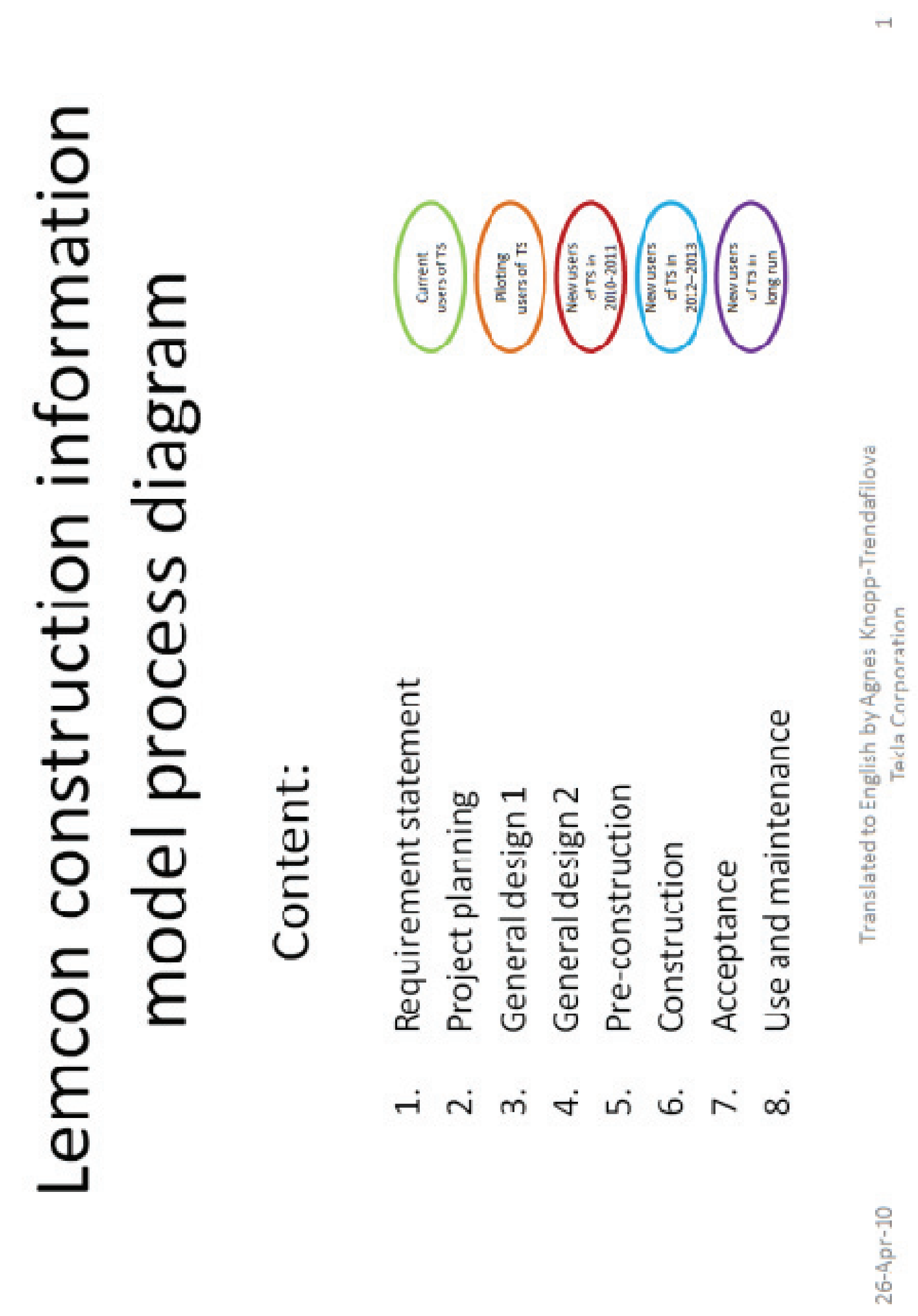
PRELIMINARIES
0 General quality requirements related to the project
SITEWORK
1 Ground investigation
2 Demolition and site preparation
3 Excavations
4 Blasting
5 Piling and soil stabilization
6 Draining and pipe work in the ground
7 Substructures and frost protection
8 Paving and surfacing
9 Vegetation work
STRUCTURAL WORK
Structural work in situ
10 Concrete
11 Masonry
12 Structural timbers
13 Structural steel
14 Structural aluminum
Structural component work
15 Component work of concrete and lightweight aggregate concrete
16 Component work of autoclaved lightweight concrete
17 Component work of timber
18 Component work of glue laminated timber
19 Component work of metal
Protective work
20 Heat insulation
21 Sound absorption and noise insulation
22 Water and moisture protection
23 Sealing and damp-proofing
SUPPLEMENTARYCOMPONENTWORK
24 Doors
25 Windows
FINISHES
Coating
26 Plastering
27 Screening
28 Painting

Timber and board finishes
29 Timber lining and flooring
30 Parquet flooring
31 Chipboard lining
32 Fiber board lining
33 Plywood and laminated wood lining
Mineral finishes
34 Plasterboard lining
35 Mineral board lining
36 Mineral board external cladding
37 Mineral sheet overlap roofing
38 Concrete roof tiling
39 Ceramic wall and floor tiling
40 Natural stone tiling
41 Glazing
Metal finishes
42 Steel sheets finish
43 Aluminum sheet finishes
44 Copper sheets finish
Flexible sheet finishes
45 Textile carpet flooring
46 Plastic sheet flooring
47 Plastic sheet lining
48 Linoleum flooring
49 Cork sheet and tile flooring
50 Wallpapering
FIXTURES
51 Fittings
52 Equipment
SERVICES
53 Construction work in connection with mechanical and electrical installations

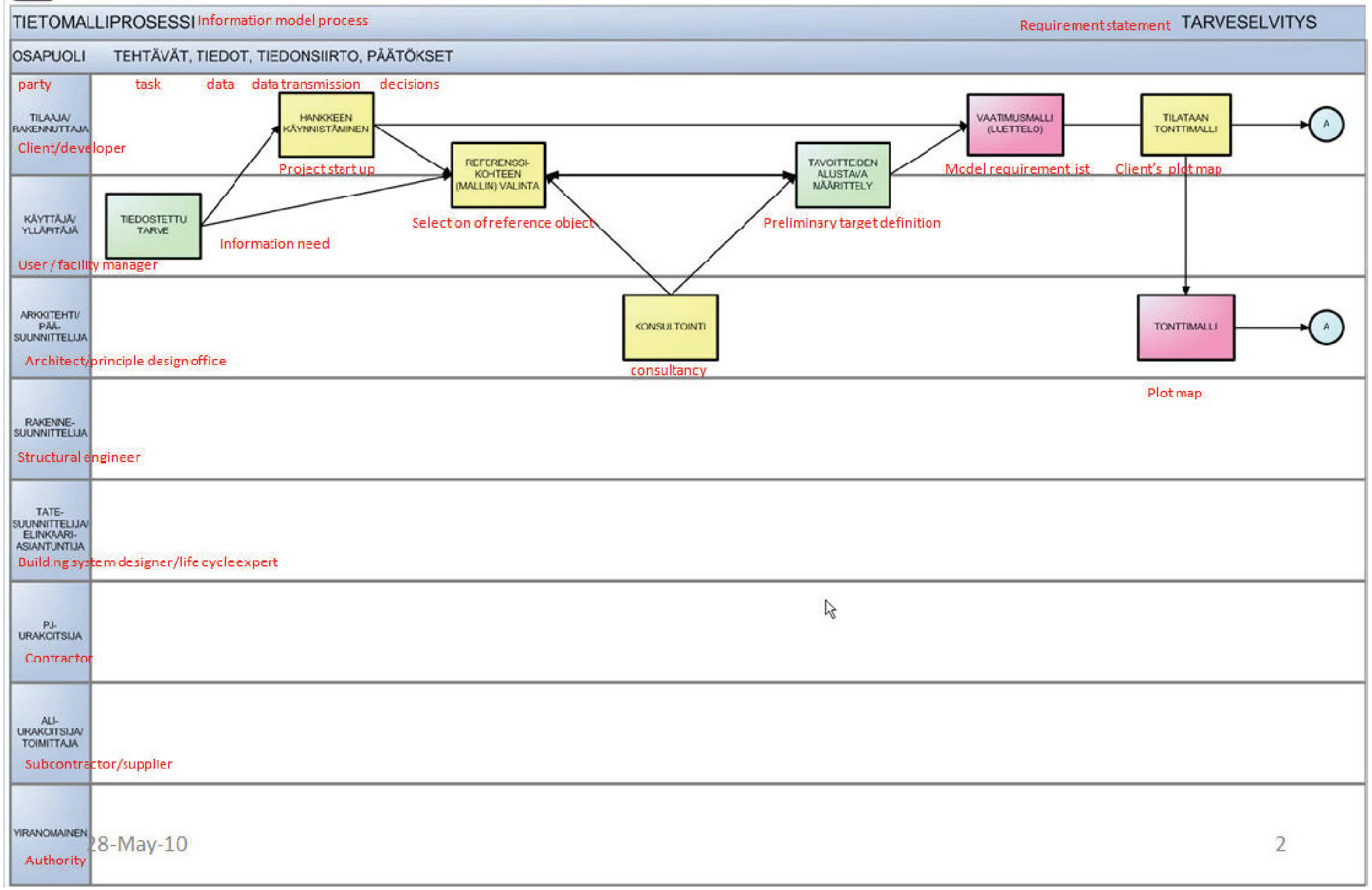
NB. The technical requirements of heating, ventilation, plumbing and sewage as well as electrical services are covered by separate Codes of Practices.

APPENDIX 5. CONSTRUCTION PROCESS DIAGRAMM

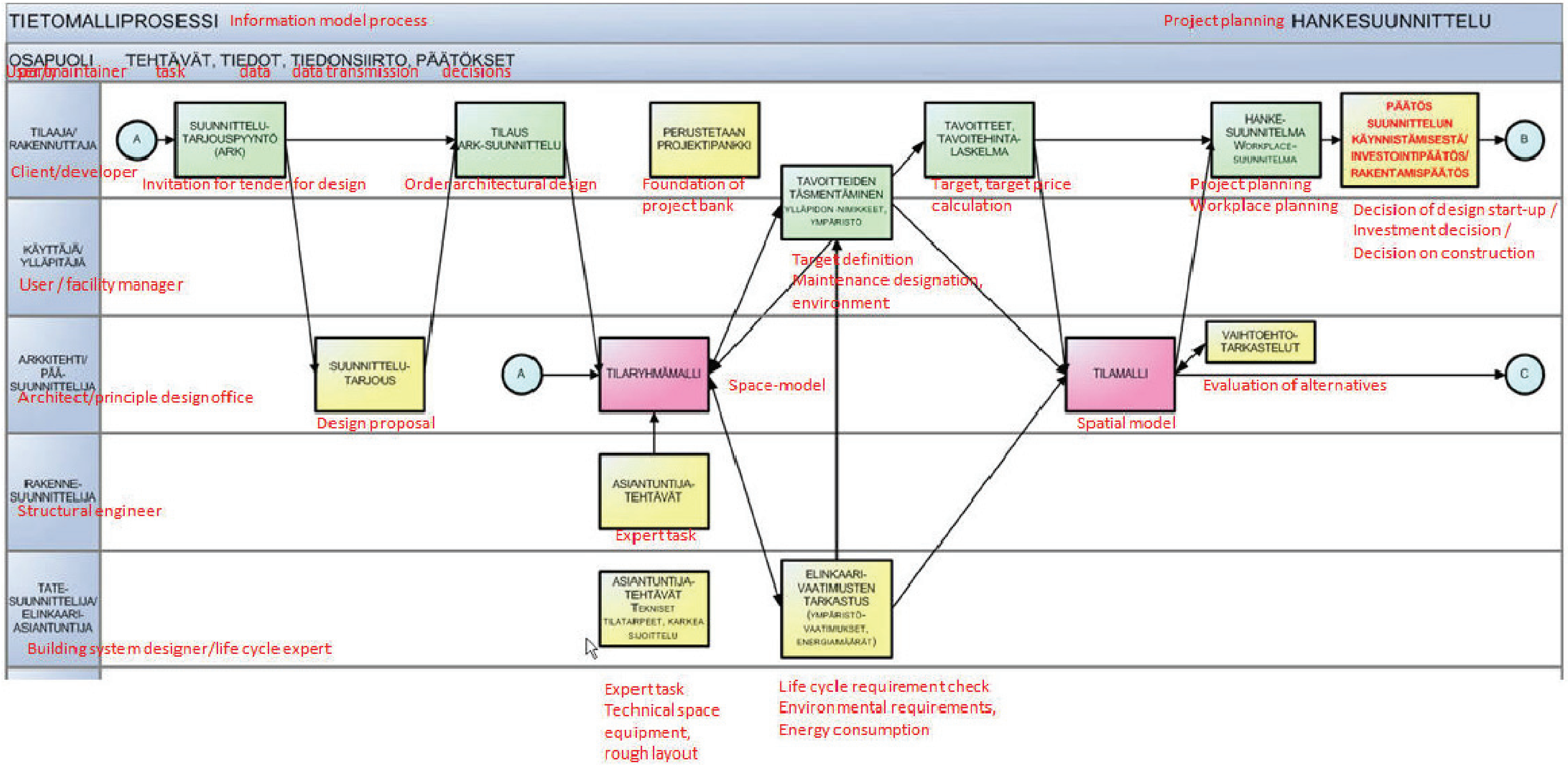
Parties involved in the creation of the process diagram are Lemcon Ltd, Senate Properties, Finnmap Consulting Ltd., Insinööritoimisto Olof Granlund Ltd., CEJ-Arkkkitehdit Ltd., Ovenia Ltd and personnel of Helsingin Yliopisto.



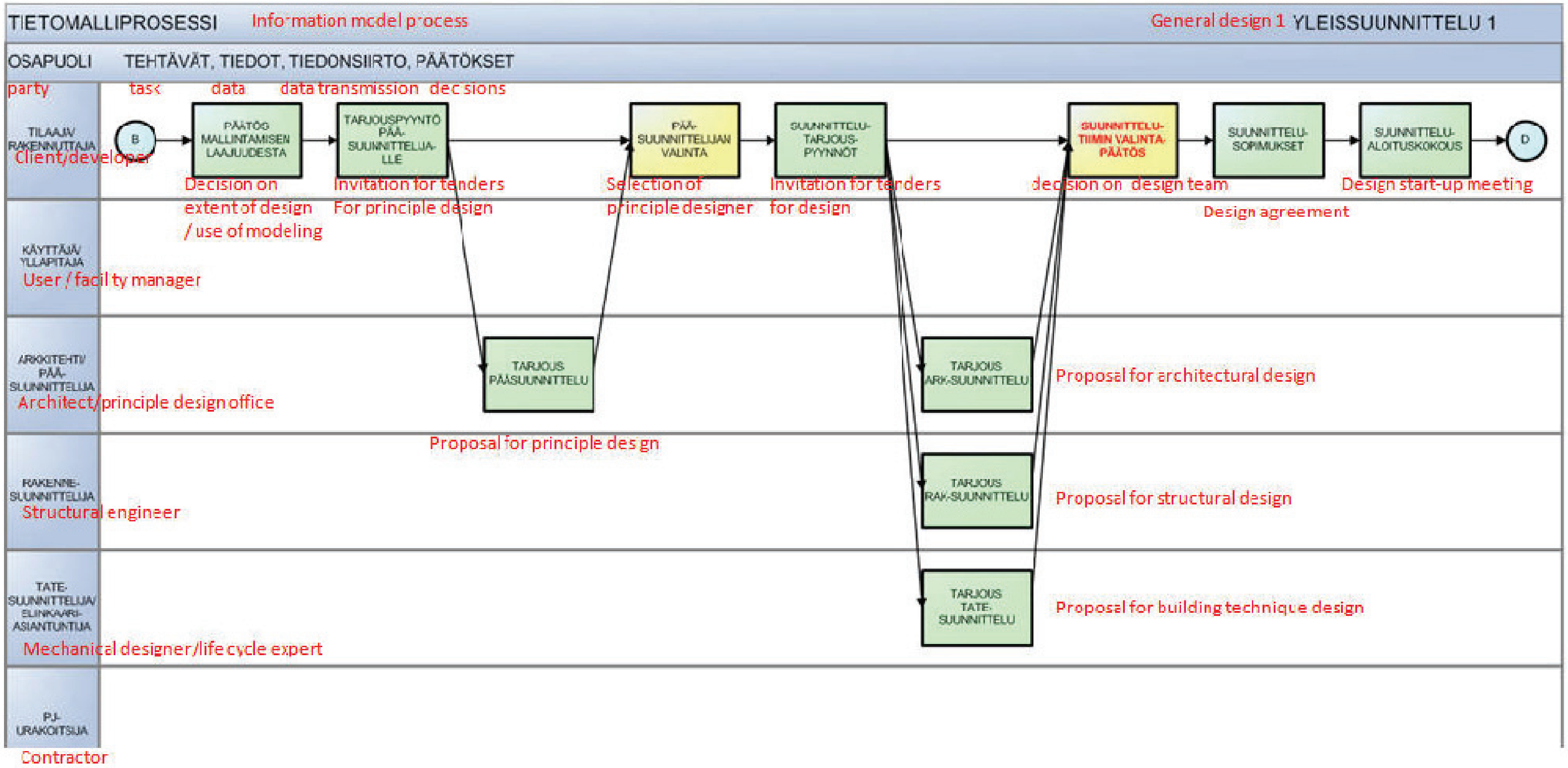
1. Requirement statement



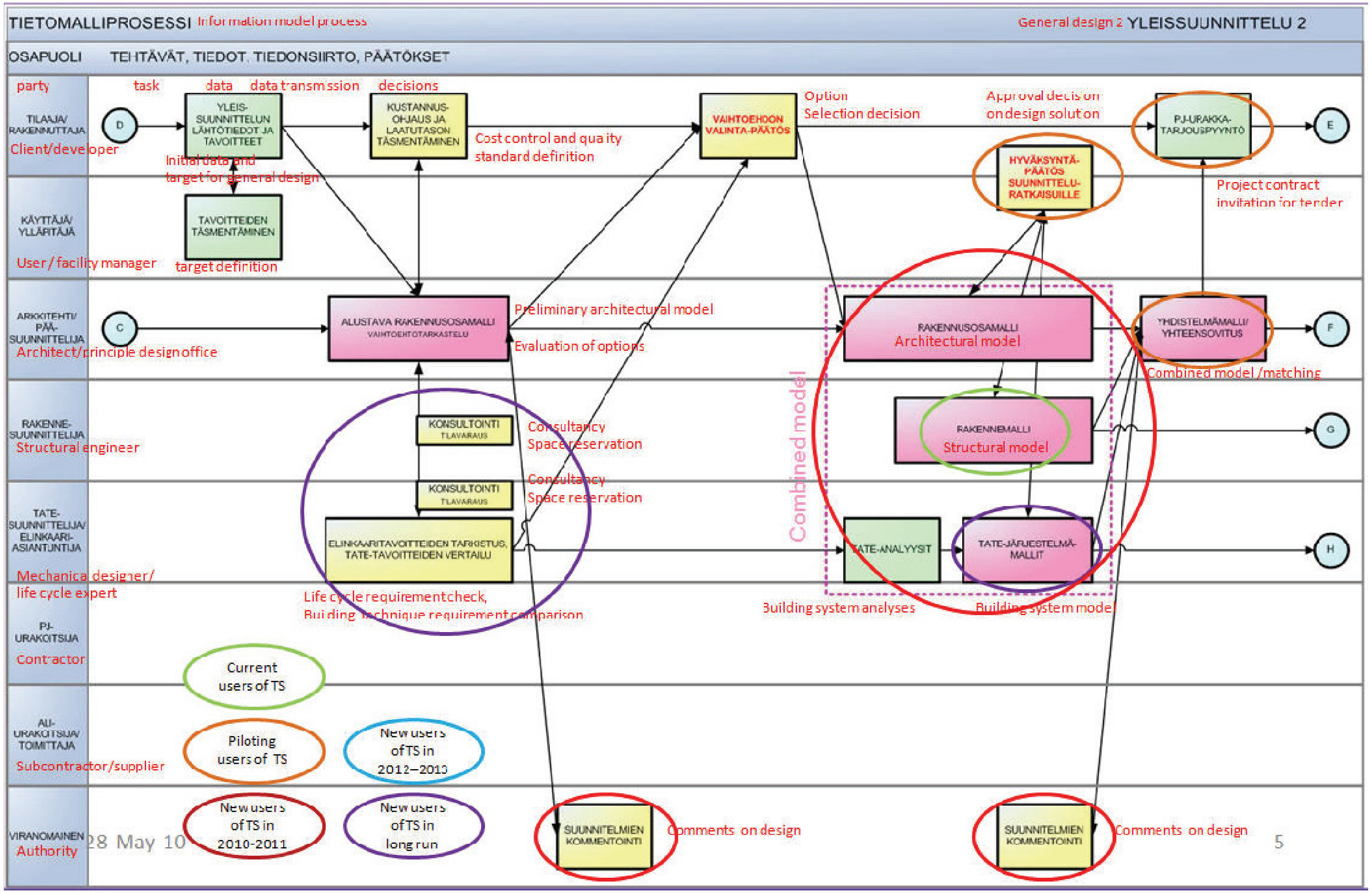
2. Project planning / Pre-construction phase



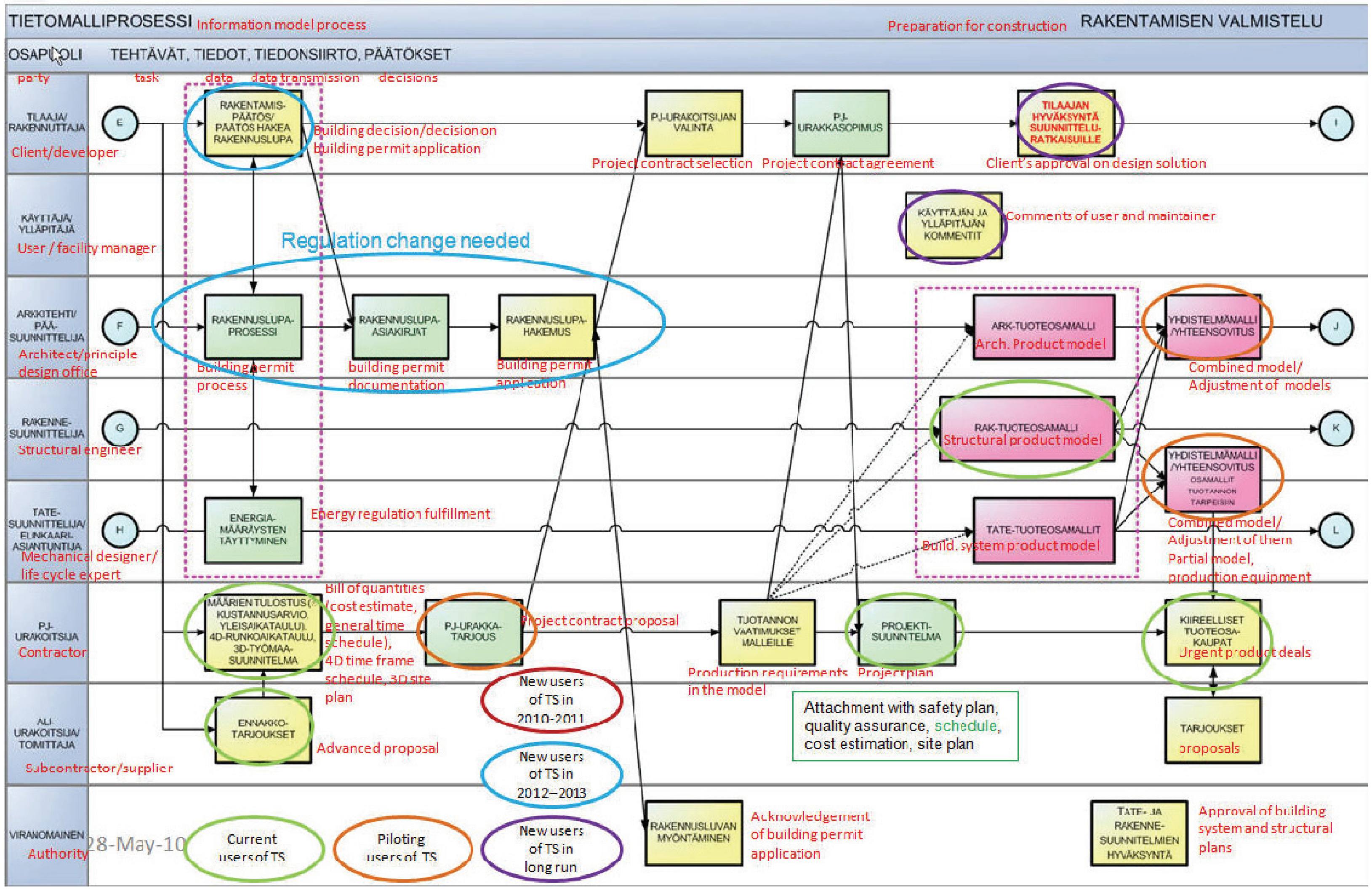
3. General design 1



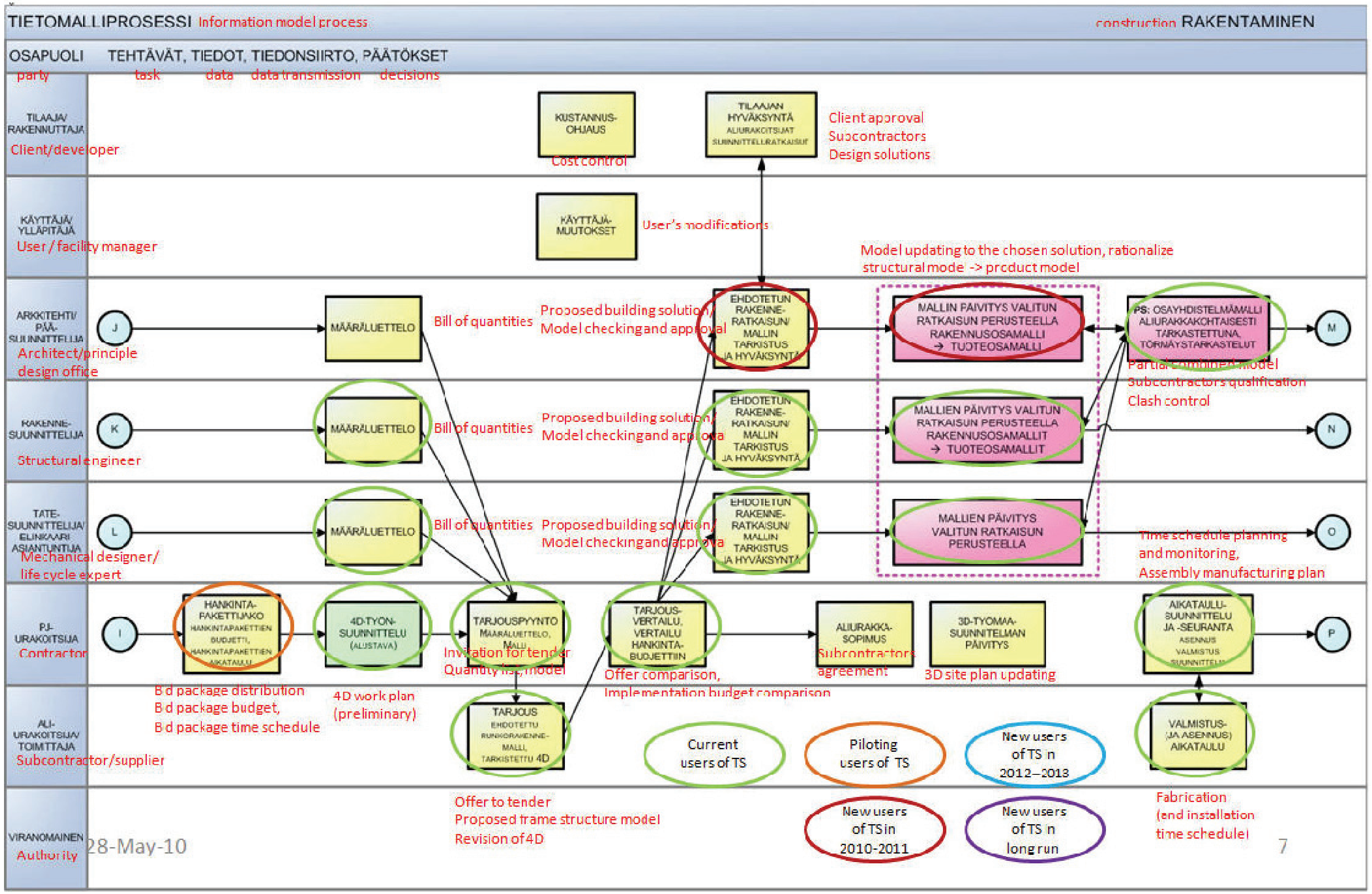
4. General design 2



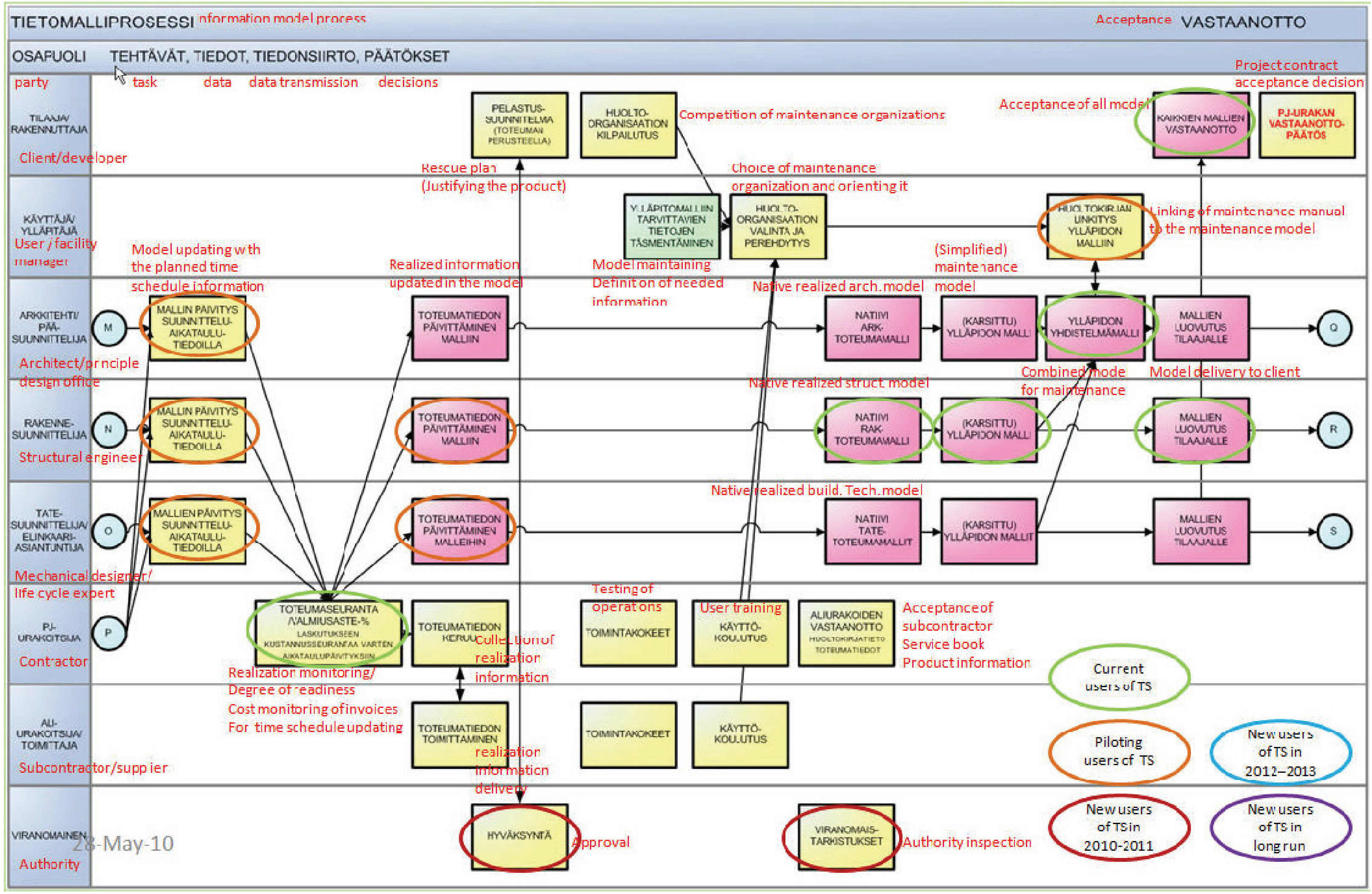
5. Pre-construction



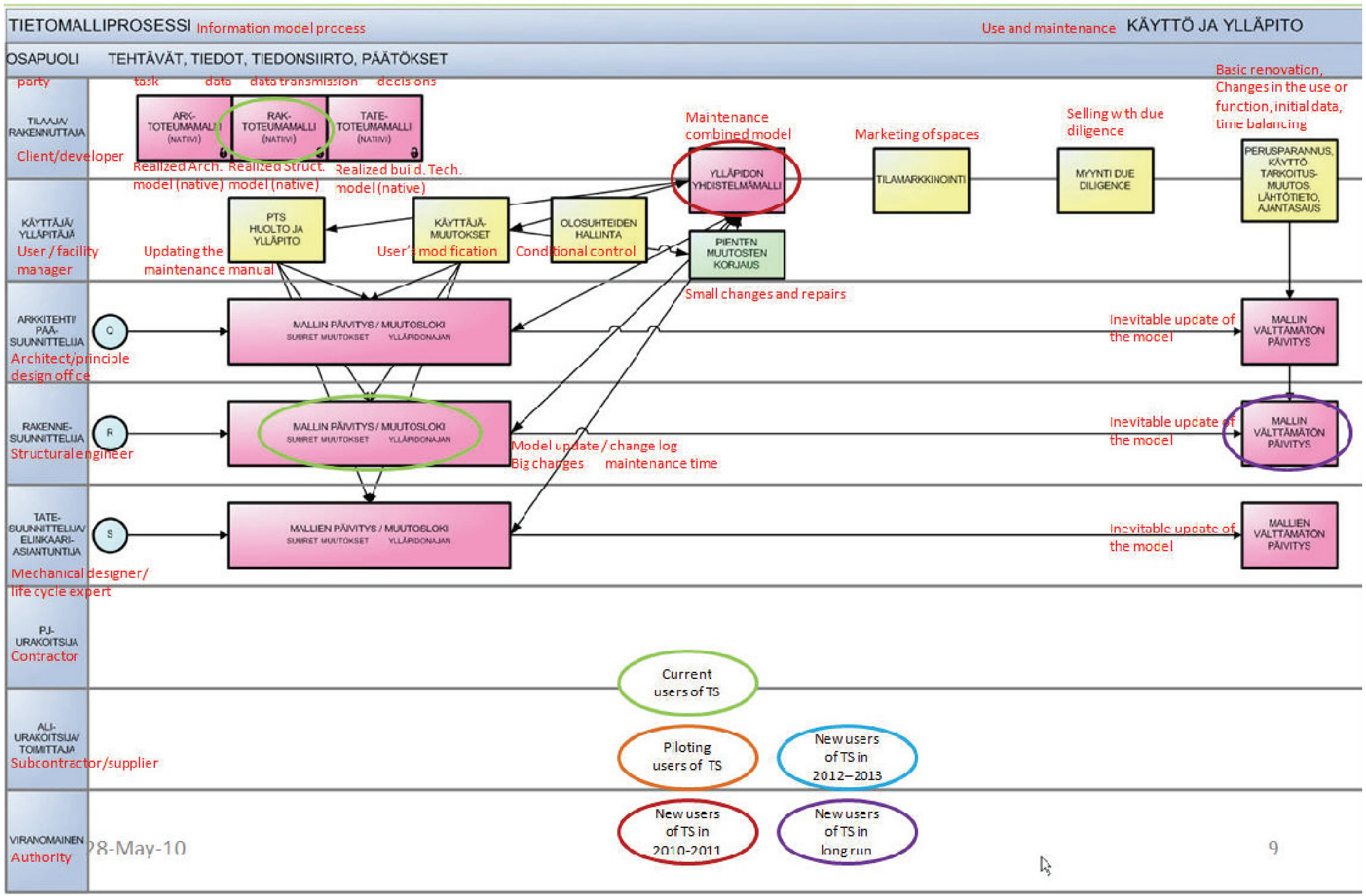
6. Construction



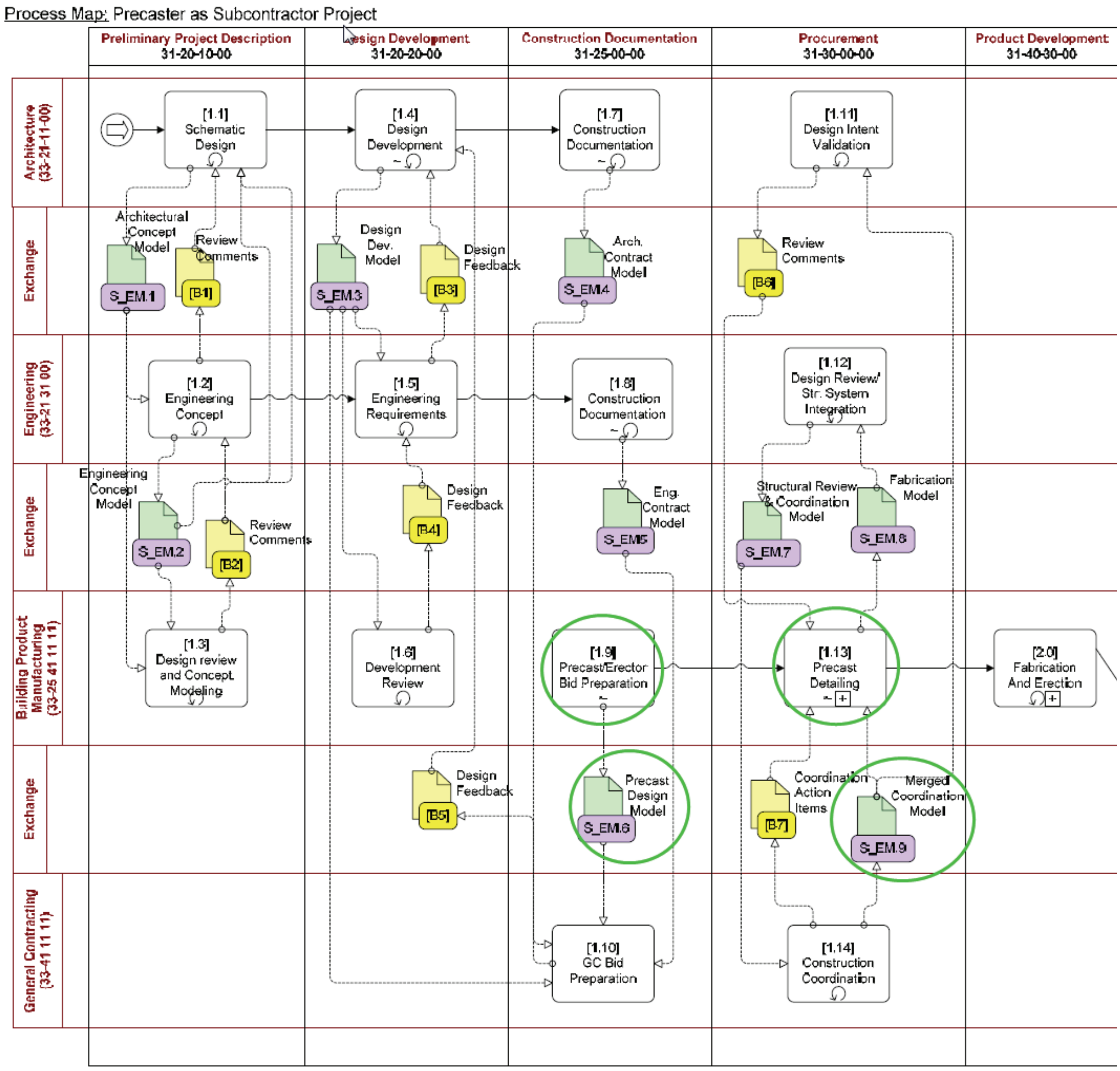
7. Acceptance



8. Use and maintenance



APPENDIX 6. PRECAST CONCRETE PROCESS IN THE USA



Process Map: Fabrication & Erection