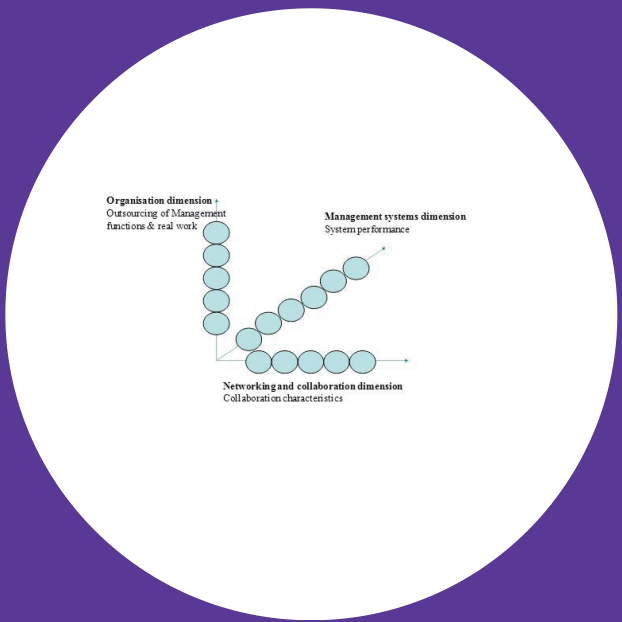
Department of Civil and Structural Engineering

Two Models for Managing the Virtualisation of Construction Management Firms in the Context of Finnish Construction Markets

Wafa Alsakini



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DOCTORAL DISSERTATIONS

Wafa Alsakini

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Wafa Alsakini

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Abstract

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Abstract

During the deep recession in Finland in the early 1990s, construction management (CM)-based competitive pressures caused many traditional building contractors to change their organising strategies via a vision characterised as a virtual contractor. In the 2000s, the realisation of such a vision has been enabled via IT infrastructures and fast developments in ICT. The twofold objective of this dissertation is to choose the relevant dimensions and design a model of virtuality, as well as to design an ideal model of a virtual CM services company (VCMSC) and its management system. The principles of core competencies, outsourcing, networking and IT systems strategies were adopted from within the literature as the theoretical bases for model design. The semi-novel, generic model of virtuality was designed along the three dimensions of collaborative management system, outsourced operations and competitive networking in order to assist the top management in companies to restructure and strategise towards virtual business performance. In turn, a novel model of an ideal VCMSC was designed to exhibit the best characteristics along the three dimensions of virtuality. This model can be used as a reference value and a tool for measuring degrees of virtuality within individual companies. The ideal VCMSC is a dynamic system with an IT-based integrated management system, where networked companies reconfigure around a lead member and a flat organisation nurtures a competitive network of special system contractors (SSCs), designers and a staff pool. The three-dimensional virtuality model was validated in terms of the theoretical ideal VCMSC model as a measurement tool of companies' actual degrees of virtuality via theme interviews and self-assessment questionnaires with ten companies in the Finnish construction industry. The interviews revealed that these companies are far from being virtual and that virtualisation is understood as merely using IT to enhance productivity and increase competitiveness. The contributions of the study point out a need for collective moves along all the three dimensions for an ideal-like virtualisation on both company and project levels in terms of (i) integrating project management (PM) and network management systems, (ii) outsourcing functional units and project staff and changing procurement strategies towards larger work packages to be procured from among SSCs, and (iii) contracting project-specific capabilities and managing a portfolio of collaboration forms with members in a competitive network.

Keywords Construction management, construction markets, Finland, interviewing, literature review, model design, virtuality.

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Tiivistelmä

1990-luvun alussa monet perinteiset talonrakennusyritykset muuttivat organisaatiotaan virtuaalisten urakoitsijoiden suuntaan johtuen projektinjohtopalveluyritysten luomista kilpailu-paineista syvän laman vallitessa Suomessa. 2000-luvulla suunta jatkui perustuen IT-infra-struktuuriin ja ICT:n nopeaan kehitykseen. Tutkimuksen tavoitteena on valita relevantit ulottuvuudet ja suunnitella malli virtuaalisuudesta niiden mukaan sekä suunnitella malli virtuaa-lisesta projektinjohtopalveluyrityksestä ja sen johtamisjärjestelmästä. Teoreettisiksi perusteiksi valittiin ydinosaamisten, ulkoistamisen, verkottumisen ja IT-järjestelmien periaatteet. Yleinen, uutuusarvoltaan keskitasoa oleva virtuaalimalli suunniteltiin yhteistoiminnan kattavan johtamis-järjestelmän, ulkoistettujen toimintojen ja sisäisesti kilpailevan verkon ulottuvuuksien mukaan niin, että yritykset voivat strukturoitua uudelleen ja strategoida virtuaalisen liiketoiminnan suun-taan. Korkean uutuusarvon omaavan virtuaalisen projektinjohtopalveluyrityksen malliin sisällytettiin parhaat ominaisuudet em. virtuaalimallin tilassa. Virtuaaliyritysmallia voidaan käyttää vertailuarvoina ja työkaluna mitata yritysten todellisia virtuaalisuuden asteita. Se on dynaaminen järjestelmä. Integroitu, IT-perusteinen johtamisjärjestelmä mahdollistaa jäsenten koonnin johtavan yrityksen ympärille. Matala organisaatio pitää yhdessä sisäisesti kilpailevien erikoisjärjestelmäurakoitsijoiden verkkoa, suunnitteluyrityksiä ja henkilöstöpoolia. Validiteetti-tarkastelu rajattiin koskemaan virtuaali- ja virtuaaliyritysmallien käyttökelpoisuutta työkaluna, jonka avulla mitataan yrityksen todellisen virtuaalisuuden asteita. Teemahaastattelujen koh-teena on 10 yrityksen joukko Suomen rakennusteollisuudesta. Haastateltavien itsearviointiin perustuvat tulokset paljastivat matalat virtuaalisuuden asteet ja sen, että virtuaalisuus ymmärrettiin tuottavuuden ja kilpailukyvyn kohottamiseksi perustuen IT:n hyödyntämiseen. Kontribuutiona on se havainto, että yritys voi virtualisoida itseään samanaikaisesti kolmen ulottuvuuden mukaan yritys- ja projektitasoilla (i) integroimalla projekti- ja verkkojohtamisen, (ii) ulkoistamalla toimintonsa ja henkilöstönsä sekä uusimalla hankintastrategiansa laajemman paketoinnin ja erikoisjärjestelmäurakoinnin suuntaan, (iii) sopien tarvittavista osaamisista projektikohtaisesti ja hyödyntäen useampia yhteistoimintamuotoja verkoston jäsenten kanssa.

Avainsanat Haastattelututkimus, kirjallisuustutkimus, mallin suunnittelu, projektinjohto, rakennusmarkkinat, Suomi, virtuaalisuus

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In memory of my beloved sister "Sema"

We miss you

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Fahim Alnishawi, Amir Jangizi and his dear wife Hannele, Eman Kassir, and the ladybirds/Turku for their sincere friendship and love… I couldn't ask for more.

Finally my family. I am most indebted to my parents, brothers, nephew, and the apples of my eye, my two sons for their love, kindness, continuous encouragement and support, and most of all for just being in my life and sharing with me what makes life worth living. I would like to express my happiness for having finished my thesis, and despite the hardships along the way, I want to look back and remember only the good times and the friendships that will remain a precious part of my life.

Above all I thank Allah, Almighty GOD, for his mercies on me and my family.

19 March 2012

Role of the researcher

This doctoral dissertation has been prepared within the unit of Construction Management and Economics (CME) at the Helsinki University of Technology (between 2005-2009) and at the Aalto University (between 2010-2011). The important roles of supervising, instructing and tutoring the researcher have been allocated to:

- Professor Juhani Kiiras, Supervisor and Instructor
- University Teacher, Lic.Sc. Pekka Huovinen, Tutor.

The scientific ground for this dissertation has been laid by the researcher, who has extensively and solely studied the relevant literature.

The partial results and early conclusions of this study were published at the international conferences in Helsinki (NordNet 2004 and CIB 2005, 2006), Montreal (ASCE, ICCCBE, DMUCE, CIB-W78 & W102, 2006) and Helsinki (CIB 2008) as well as in the Encyclopaedia of Networked and Virtual Organisations. Altogether, there are eight papers that have been co-authored by the researcher (as the prime author and presenter), the supervisor and the tutor. Each of these eight papers has been relied upon as the reference of the dissertation.

The interviews representing the ten case companies have been conducted solely by the researcher both during the preliminary investigation and later during the theme interviews.

The authentic, case company-specific documentation, including the scaled self-rating by the top management of case companies, were collected by the researcher herself. The first supervisor verified its existence and he is acquainted with its contents. The detailed descriptions of the participating case companies were also verified by this supervisor and were disclosed to protect the anonymity of the case companies and their representatives.

19 March 2012 Signed by

WafaAlsakini

I hereby declare that the role of Wafa Alsakini in this study fully complies with the criteria for the independence as set for a dissertation.

Juhani Kiiras
First Supervisor

Instructor

Two Models for Managing the Virtualisation of Construction Management Firms in the Context of Finnish Construction Markets

LIST OF TABLES

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LIST OF ABBREVIATIONS

A/E	Architect (firm) and engineer(ing firm)
APP	Building project activities, their planning rules, and interdependence
BCIM	Building construction information model
BCPM	Building construction process model
BPM	Building product model
BPRCM	Building project resource and cost model
CAD	Computer-aided design
CASSMS system	Commissioning and after-sales services management
CM	Construction management
CPECMS management system	Construction planning, execution, and control
CPM	Critical path method
CRM	Customer relationship management

DV	Degree of virtuality
FM	Facility management
ICT	Information and communication technologies
IS	Information system
IIS	Integrated information system
IT	Information technology
LoB	Line of balance
NNMS	Network nurturing management system
NPPMS	Networked project procurement management system
OL	Organisational learning
O&M	Operation and Maintenance
PDEMS	Project design and engineering management system
PM	Project management
POBMS	Project offering and bidding management system
PORMS	Project owner relations management system

RSP	Resource structure and prices
SME	Small and medium-sized enterprise
SSC	Special system contractor
VC	Virtual company
VCMF	Virtual construction management firm
VO	Virtual organisation
QM	Quality management

1. INTRODUCTION

This dissertation is driven by the previous and still ongoing efforts in the construction industry in order to develop new concepts and systems for managing a virtual construction-related firm. The focus of this study is on construction management (CM) firms. The rationale for this focus is justified by referring to the accounts of the CM forms in the case of Finland. Aligning with the key contributions within the virtual organisation literature, a definition for a virtual CM firm is formulated.

1.1 Background

As the possibilities of the information revolution challenge traditional business logics, firms are experimenting with an array of strategic alternatives and organisational forms. The current models are inadequate for meeting these imminent challenges. The increasing performance of new information and communication technologies (ICT) has enabled many new organisational models of coordination and cooperation. Since the early 1990s, **virtual organisations (VOs)** have been the focus of scientific research. The most postulated characteristics and advantages of the new ICT-enabled organisational model include increased competitiveness, customer-focused business and service models, and high flexibility in a rapidly changing environment (Venkatraman & Henderson 1998).

Factors pushing for (causing) changes in organisation structures are related to globalisation, changes in market structures, consumer needs and technology innovations (Bauer & Köszegi 2003 and Saabeel et al. 2002). External forces and employed business strategies lead to changing business understanding, which in turn instigates organisational change. Firms are increasing flexibility and decreasing complexity to meet changing market conditions. Many firms adopt **core competence strategies**, i.e. they concentrate on what they do best, specialise in certain areas, develop and improve their core competencies and search for value chains where they can integrate their core competencies with those of other economic actors,

which theoretically will lead to an optimum value creation process (Balint et al. 1998). Other firms network in order to increase access to information and enhance the use of information for the creation and transfer of knowledge. Besides outsourcing, supply networks involve interrelated factors such as (i) the efficiency of activity patterns, (ii) innovative and value creating resource constellations, and (iii) powerful actor webs (Gadde & Håkansson 2001). **The emerging paradigm of networks** (collaborative organisations) is changing the ways of organising industrial, commercial, cultural and social activities (Franke 2001, Fleisch & Österle 2000). Tasks are being performed by autonomous teams or independent firms that are linked as a network. Actors are likely to sacrifice some of their own performance in pursuit of collective goals. Networks are characterised by a purpose and shared goals that unify members who benefit from being part of a whole. Voluntary links between members and multiple leaders provide great resilience. Thus, traditional organisations are evolving towards or even replaced by dynamic networks of collaborating entities that reconfigure around a virtual organisational entity.

In turn, **the construction industry** is project-based and fragmented. It deals with great transactions and it seldom sustains the same clients. A typical construction project involves an ad hoc team of firms. Each firm only deals with certain aspects and very often is only interested in improving own profitability. Similarly, fundamental global changes are causing construction organisations to radically review what business they are in, what products and services they provide and how to be more competitive. Many leading organisations have already responded to this need for change through information technology (IT). By the mid-2000s, a large number of software programs had been developed and the usage of IT in construction was already growing steadily across national contexts (e.g. in the UK; Betts 1999, Sun & Howard 2004).

1.2 Dual focus of the study

1.2.1 Generic focus on Vos

It seems that the certain characteristics of VOs are primarily contributing to a collective definition of virtuality. In the management literature, **virtualness** is treated as a strategic characteristic. Accordingly, an organisation is considered virtual by the way it is managed rather than simply using ICT systems or self-appointing itsef as a VO. Virtualness is an

ability to consistently obtain and coordinate critical competencies through the design of value-adding business processes and governing mechanisms involving external and internal constituents for the delivery of superior value in the marketplace (Venkatraman & Henderson 1998: 33-48). One of VO's key characteristics is **alteration**, i.e. an ability to include external parts in order to complete a value creation process. A dynamic alteration in real time between partners in a value chain allows an ad hoc organisational structure for creating customised products (Franke 2001: 43-64). In turn, a process of **switching** describes a virtually organised task as a goal-oriented activity that is implemented by an appropriate assignment of satisfiers to the requirements of the task. At any moment, there is an allocation of satisfiers to the requirements but a particular allocation changes over time. This systematic and dynamic switching capability is perhaps the most important characteristic of a VO and therein lies its flexibility and efficiency (Mowshowitz 1999: 7-18).

Collectively, a VO can be defined as **an evolving organisational paradigm** that has an ability to alter its value creation process by applying a principle of switching. A VO is an organisational construct which delivers its high customer value through the constant allocation and dynamic assignment of its process parts to satisfiers that have been selected, based on the requirements and other factors relevant to competitive advantage. A VO may also be defined as an entity that is capable of dealing with complexity and uncertainty through cooperation among members in a network that is managed like a single organisation. The goal is to create and nurture flexibility for meeting changing market conditions by employing a core competence strategy, extending their value chains, and integrating many core competencies of their stakeholders (Venkatraman & Henderson 1998, Franke 2001, Mowshowitz 1999).

1.2.2 Applied focus on CM firms

This study focuses on a context of **CM firms**. As a practice in construction, the general CM context involves practitioners who are needed to perform CM services for owners (clients) of buildings. A vast range of expertise and a demand for timely performance preclude complete CM services by a single firm except on very simple projects. As a result, many CM firms are multi-discipline organisations. The organisation and make-up of a CM firm is unique in the construction industry, neither a contractor nor an architect/engineering (A/E) firm can match its functions or personnel

(Haltenhoff 1999). CM is defined as a management system for promoting the successful execution of projects for owners. A main consideration is whether a construction manager takes on the responsibility of a constructor for a guaranteed maximum price or performs an administrative role as an agent to an owner. Thus, CM is practiced in two general forms of agency CM and/or CM-at-risk, where differences are determined in terms of service providers and a responsibility assignment, a risk distribution and a compensation method (Haltenhoff 1999, Oyegoke 2001, Kiiras et al. 2002).

In the focal context of the Finnish building sector, the deep recession during the early 1990s resulted in the establishment of both CM-for-fee consultants and CM-at-risk contractors with their lean organisations. The large buildings were increasingly implemented under the CM contract forms (Kiiras et al. 2002). In the 2000s, the major building owners have become the highly satisfied clients as the reliance on the CM contracts has allowed them to make their decisions in more flexible ways, even during the execution phases and at the same time to avoid change orders. Thus, the top management of many traditional building contractors have considered options to change or complement their strategies and principles of organising and, thus, to adopt new ways of streamlining. All this can be characterised as **becoming a virtual contractor** (Kiiras & Huovinen 2004). The realisation of this vision is being enabled and supported via a strong IT infrastructure and information and communication technologies (ICT) development.

1.3 Objectives, research questions and limitations of the study

The twofold objective of this study is as follows: (i) to choose the relevant modelling dimensions and design a model of virtuality, and (ii) to design a model of maximum virtual CM firm (max VCMF) with its management system. Any construction company can rely on the first model of dimensions of virtuality for restructuring and strategising towards virtual business performance, and on the second model as a reference model and a tool for measuring their actual degrees of virtuality.

Accordingly, the research questions are posed as follows: (i) Why and how should a CM firm virtualise? (ii) How can we measure the degrees of virtuality of a CM firm? (iii) How can such a virtual CM firm be managed? and (iv) What is the range of variation in virtuality in the Finnish context?

The research assumptions underlying the model design include: (i) a flat organisation of a virtual CM firm is achieved by outsourcing functional units and real construction work, (ii) the effective collaboration is managed with the new types of members, i.e. a competitive network of special system contractors (SSCs), and (iii) the integration of a management system of a virtual CM firm is enabled via a three-part building construction information model (BCIM).

The application area of the suggested virtual CM firm model and its IT-enabled, integrated management system involves the requirements for the viable scope of future contracts or projects, i.e. such innovative, virtual entities need to target unique, large and complex buildings. In other words, the repetitive or serial production of similar housing buildings and such like is outside the viable application area.

1.4 Structure of the report

In Chapter 1, the background, focus and focal context of this study are introduced. The twofold objective is set and the four research questions are posed. The key assumptions are defined for designing a model of virtuality and a theoretical model of a maximum virtual CM firm (max VCMF). For this study, the Finnish CM concepts are applied. The application area is limited in terms of the scope of viable CM contracts (buildings).

In Chapter 2, the research methodology is selected, described and justified and the constructive research approach is applied. The anticipated practical problem is coupled with the relevant research problem of virtualising a CM firm and designing its management system. The design of a dimensional virtuality model and a max VCMF model is planned. The qualitative method is selected in order to tackle an empirical investigation of the applicability of the two models, mainly via the benchmarking by using the self-assessment questionnaires that are complemented by the theme interviews.

In Chapter 3, the results of a foundational literature review are presented concerning virtuality, VOs and virtualisation strategies in general. The basic concepts that contribute to the design of the dimensional virtuality model and the max VCMF model are highlighted. CM practices in general and in the focal context of Finland are introduced. ICT is also recognised as an enabler of virtuality.

In Chapter 4, the three-dimensional virtuality model and the max VCMF model are both designed. The latter is coupled with the design of an IT-based, integrated network and project management (PM) system and the two sub-models of a building construction information model and an integrated information system.

In Chapter 5, the conduct of the benchmarking process concerning the three-dimensional virtuality model is planned in terms of the adaptation of the max VCMF model as a measurement tool, the interview data collection and processing, and the reporting. The results of the benchmarking process are reported upon in detail, by each of the three dimensions of virtuality. The results of the cross-case company analysis are also presented and interpreted.

In Chapter 6, the discussion concerns the model design task in terms of the applicability of the selected theoretical bases, the virtuality model and the max VCMF model as the two theoretical constructs, the applicability of the max VCMF model as a measurement tool, and the accuracy of the benchmarking. This chapter includes also the conclusions and the suggestions in terms of the study's contribution to theoretical knowledge and the implications to researchers as well as the applications in the real world.

In Chapter 7, the objective setting, conduct, and results of the study are summarised. The conduct and contribution of the study are condensed and the suggestions for future development are presented.

2. RESEARCH METHODOLOGY

In this chapter, the methodology that governs the study is chosen and planned. The choices that are both included and excluded are justified. The methodology is planned in order to produce the relevant replies to the research questions. In addition, the planning and conduct of the benchmarking process is reported in more detail in subchapter 5.1.

2.1 Reliance on the constructive approach

In general, the choice of a research approach is based on a research problem(s) and ultimately questions to be answered by a study. When choosing a research method, researchers, in their attempt to generate simple, accurate and general research styles, might very well end up making trade-offs (Weick 1979).

The **constructive research approach** (Kasanen et al. 1993) has been selected and applied to the phasing of this study. The research problem and its solution are based on the theoretical knowledge of virtuality in general and the contextual knowledge on the traditional and virtual practices and developments in the focal context of the Finnish construction industry. Both the practical and theoretical problems of virtualising a construction company effectively are approached by planning, making and validating the design of a novel construct or a conceptual model.

2.1.1 Choice of the constructive research

The constructive research approach is "a research procedure for producing constructions. Constructions refer in general terms to entities which produce solutions to explicit problems" (Kasanen et al 1993: 243-264). An important characteristic of constructions is that their usability can be demonstrated through the implementation of a solution. Accordingly, the constructive approach is valid for managerial problem-solving through the construction of models, organisations, plans, etc. An essential part of the

constructive approach is to tie the problem and the solution to accumulated theoretical knowledge, so that the novelty and actual working of the solution have to be demonstrated. The constructive approach can also be understood as a particular mode of conducting field research, it tends to add a strong problem-solving type of intervention and an attempt to draw theoretical conclusions based on the empirical work. When seeking a solution through constructive research, a researcher performs **the three main phases** as follows (Lukka 2000): (i) to develop a solution model (construct), (ii) to test the functionality and usability of the model, and (iii) to study the applicability of the model and connect it to existing theoretical knowledge.

One of the core features of the constructive approach is to focus on real world problems, the solutions to which would be relevant in practice. As a starting point, a researcher should find one or more practically relevant problems that firms and practicing managers are facing in reality and which have a research and theoretical contribution potential (Lukka 2000). Nevertheless, it is perceived that **this study could be planned and phased according to the constructive approach**. Instead of real life problems, the starting point involves the anticipation of future competitiveness problems that virtualisation will cause sooner or later across various national building construction industries or sectors. Otherwise, the logic and the remaining phasing of this study have been planned according to the constructive approach.

2.1.2 Conduct of the constructive study

The twofold objective of this study has been attained to a large extent by producing the relevant replies to the four research questions (p. 3). This was accomplished during the overlapping phases of reviewing the selected literature, designing the dimensional virtuality model and the max VCMF model, and probing the practical applicability of the latter with the help of the interviews, redesigning the preliminary models, and finally using the three-dimensional virtuality model for benchmarking the Finnish CM firms in terms of the max VCMF model. The **six overlapping phases of this study** correspond to the constructive research phases (Figure 1). The conduct of each phase is reported as follows.

Phase 1. “How should a CM firm virtualise itself?" and "What kind of management system will support virtual processes?" were chosen as the

two key research questions that will also have an increasingly practical, problematic relevance in the future. (1.1) A review of the foundational literature was carried out in order to gain an understanding of the concepts of virtuality and VOs. The references cover the evolving concepts published from the early 1990s up to the mid-2000s. (1.2) A concurrent review of construction-related literature was carried out to gain an in-depth understanding of virtuality and virtual practices in this focal context. Most contextual references aimed at advancing the virtualisation of project teams and tools, workplaces and project sites. This generic and contextual understanding allowed the researcher to formulate a guiding definition for what virtualisation means and to reflect its relevance to this study.

Phase 2. A generic framework was designed for approaching the problem. With the help of this preliminary framework, (a) the researcher pre-designed a conceptual max VCMF model as a reference model for firms, (b) the researcher also designed an IT-based management system for managing a max VCMF, and (c) in principle, any firm can guide its path towards virtual PM performance and choose its targeted degrees of virtualisation. At this stage, only one dimension of virtuality was defined without any intention of ending up with all three.

Phase 3. (3.1) The generic, theoretical bases were found from among the recent, focused literature. This enabled (3.2) the design of a preliminary max VCMF model and its IT-based management system. The preliminary management system was designed only along the management dimension of virtuality in order to measure the levels of IT-based management functions and processes within firms. (3.3) The pre-testing of the preliminary model for measurement purposes was performed by the exploratory, semi-structured interviews with the selected Finnish practitioners.

Phase 4. Concurrently, (i) virtuality was captured by defining it as a three-dimensional model and (ii) a max VCMF model was finalised together with the IT-based, integrated subsystems of a competitive network and PM model. The integration is achieved via a

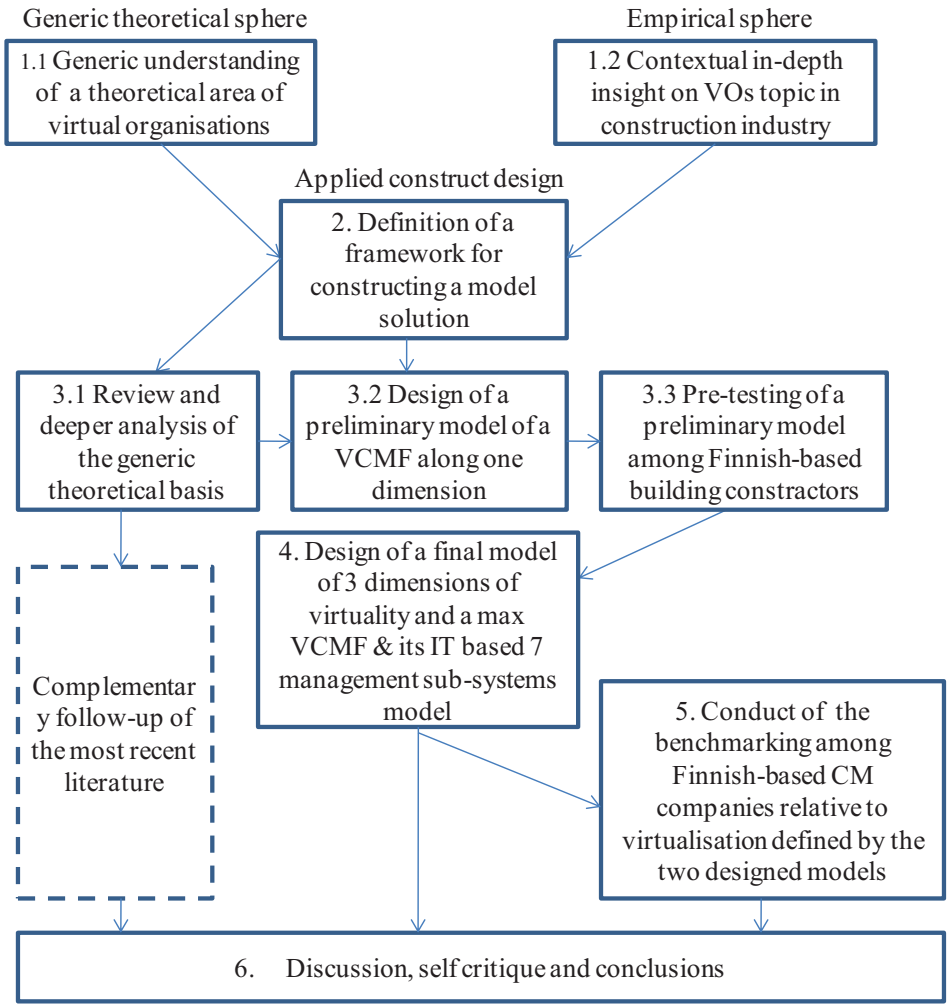

Figure 1. Six phases in the constructive research process of the study.

three-part building construction information model. In part, the finalisation was based on both the results of the preceding follow-up of the generic and contextual literature and the results of the pre-testing of the preliminary model through the interviews with the Finnish practitioners.

Phase 5. The applicability of the three-dimensional virtuality model was investigated by the benchmarking in terms of the max VCMF model as a measurement tool, i.e. for measuring the actual degrees of virtuality of the selected companies. The number of the relevant Finland-based case companies was increased to ten in order to ensure that (i) the three-dimensional virtuality is applicable for measuring degrees of virtuality of

any CM firm and (ii) the max VCMF model corresponds to the virtual futures envisioned by the potential, CM services-related exploiters (of such models) and can be used as an applicable reference model among CM firms aiming at high degrees of virtuality.

Phase 6. The conduct and results of the study were rigorously discussed and these considerations were reported in terms of (i) the applicability of the selected theoretical bases versus the model design, (ii) the validity of the defined three dimensions versus the design of the two models, (iii) the applicability of the max VCMF model in particular as a measurement tool in the focal context, and (iv) the conclusions and the suggestions vis-à-vis the novelty and contribution of the max VCMF model in comparison with the generic and contextual knowledge, the recommendations for practitioners, the future applications in the real world and the implications to researchers.

2.2 Conduct of the literature review

At the outset, it was necessary to conduct a **foundational review of literature** in order (i) to become familiar with the roots of the research problem, (ii) to find out what (if anything) has been achieved as validated and effective solutions for solving generic or contextual problems, and (iii) to learn about existing insights that can be relied upon for developing a new insight and synthesising a new solution. During the latter phases of the study, more recent literature was followed up and the existing body of knowledge was complemented in order (iv) to identify those concepts (or those elements of concepts) that can be used as references in discussing, positing and justifying the results of this study.

It turned out that there was an abundance of **cumulative, paradigmatic, generic literature** on virtuality, VOs and virtual systems (e.g. Hedberg & Olve 1997, Fleisch & Österle 2000, Franke 2001, Bauer & Köszegi 2003, Camarinha-Matos & Afsarmanesh 2003, Camarinha-Matos et al. 2005), collaborative network organisations (Camarinha-Matos & Afsarmanesh 2004), agile virtual enterprises (Goranson 1999) and virtual corporations (Davidow & Malone 1992). The researcher could choose the theoretical roots for model design from among such references published between the early 1990s and the mid-2000s.

The researcher gained a necessary understanding of **the background and contextual research problem** by conducting a combined review of

literature on CM and PM across key national contexts and virtuality in construction-related contexts. The former included many established books (e.g. Pilcher 1992, Barrie & Paulson 1992, Dorsey 1997, Haltenhoff 1998, Walker 1999). As expected, the latter was still in its infancy, i.e. most references were on virtualisation of projects, project teams and tools (Fernando 2001, Becerik 2005), workplaces and project sites (Gunaydin & Arditi 2000, Kazi 2005, Kazi & Wolf 2006, Arditi 2007) and the role of IT in construction (Betts 1999, Sun & Howard 2004). No literature could be found on the virtualisation of construction companies as wholes, organisational structures or enabling managerial and operational functions.

In this study, the design of my own theoretical constructs could be based on (i) the primary literature containing generic viable models and systems on virtuality and VOs, (ii) only some exploratory references on virtual practices in the construction industry, and (iii) many useful references on virtual processes, practices and successful performances in other industrial and (inter)national contexts.

2.3 Design of the two main models

A **preliminary framework** was constructed to capture both the likely relevant dimension of virtuality and some key characteristics of a VCMF. A **preliminary, partial model** was designed only along the management dimension to correspond to a VCMF with its IT-based management system (Alsakini et al. 2005). Contextually, a traditional building contractor in Finland was transformed into a flat virtual organisation through outsourcing. In such organisations, the middle levels of management are removed and functional units are outsourced. Prior internal staff are encouraged to act as entrepreneurs who form a staff pool, a virtualised contractor assigns key staff to each project from within this pool. Firm management is responsible for creating a network and enhancing complementary supplier relationships. A delivery system is based on competitive networking, which implies a lead member network with several SSCs that supply the same products, functional elements, or services (Tommelein & Ballard 1997).

A **preliminary IT-based management system** consists of six subsystems, i.e. managing (1) owner relations, (2) offering and bidding, (3) design and engineering, (4) procurement, (5) construction, execution and control, and (6) network nurturing (in part Lahdenperä 1998, PMI 2003). This preliminary system was used to investigate an assumption that a

degree of virtual management performance of a building construction company can be assessed with the IT-based system along this management dimension. On the one hand, the results of the **exploratory interviews** revealed that the Finnish case companies differed in their degrees of virtuality. On the other hand, it turned out that it was not valid to rely only on the six IT-based management subsystems to detect and assess virtuality along this dimension. Some complementary dimensions are needed in order to capture companies' structural and organisational aspects such as a functional (in/out)sourcing and collaboration between virtually networked members.
Overall, the outcomes of Phases 1-3 enabled the researcher to proceed with the **final model design** during Phase 4 as follows:

(1) An **applicable model** for virtualising CM firms was captured by choosing and defining the **three interrelated dimensions** of such a model, i.e. (i) IT-based integrated management system, (ii) an outsourced organisation and (iii) a collaborative, competitive network. This three-dimensional virtuality is based on the application of the theoretical knowledge of virtuality (Scholz 1998a-b, Bauer & Köszegi 2003). The researcher applied this generic knowledge to the building industry's characteristics that were revealed through the exploratory interviews with the Finnish case companies.

(2) A **final max VCMF model** was designed within the newly defined three dimensions of virtuality as a reference model and a tool for measuring the degrees of virtuality within a CM firm. Accordingly, the three key characteristics of a VCMF are (a) a flat, outsourced organisation, (ii) a competitive network of SSCs, designers and a staff pool, and (iii) an IT-based, integrated network and PM system.

(3) The preliminary management system of the max VCMF was redesigned into **an IT-based, integrated network and PM system**. The finalised system consists of seven subsystems. The five subsystems that are used for managing projects and related processes and the selected subsystems correspond to the well-known areas in generic PM (PMI 2003). The two novel network subsystems are selected for managing both client relations (e.g. Pinto & Rouhiainen 2001, Hoover Jr. et al. 2001) and a competitive network with its member relations (e.g. Gadde & Håkansson 2002, Man 2004). In turn, these seven subsystems are integrated with information flows that are enabled by a three-part building construction information model.

2.4 Conduct of the empirical investigation

One of the fundamental choices researchers have to make is to determine what type of approach they want to use to collect and analyse data for investigating applicability, i.e. whether **to tackle the empirical side of their research** with qualitative or quantitative research methods. In qualitative research, a small sample is studied in depth, qualitative data is considered holistically and the purpose can be seen as to find an explanatory model for a phenomenon or to describe a phenomenon itself (Silverman 1995). In quantitative research, the focus is on finding statistical relationships within numerical data and suitable methods are used for finding answers from a large amount of information gathered over a wide area (Bryman & Cramer 1995). Qualitative and quantitative research methods can also be used in parallel in order to shed light on the same problem from different perspectives. Combined approaches involve either a sequential process or a triangulation. For example, the multiple case study approach is useful for intensive and in-depth research on a small sample of entities. It can include both qualitative and quantitative data (Tellis 1997).

With regard to the empirical sphere, the objective of this study is **to investigate virtuality in the case companies and to measure their degrees of virtuality**. Herein, qualitative data has a strong advantage over quantitative data in allowing for an understanding of the shared meanings of practitioners. It seems that virtuality as a phenomenon is not yet that well-known among practitioners in the construction industry across various national contexts. It is herein assessed that in the late 2000s the majority of Finnish firms were including virtual work processes (mostly IT-enabled management processes) in their daily activities in order to enhance their productivity with no true understanding of why and how to become virtual. Investigating such a little understood phenomenon within the daily life of firms requires **qualitative methods** such as capturing participants' observations through both unstructured interviewing and via questionnaires to access individual and shared meanings. This is so because only qualitative methods attempt to capture and understand individual definitions, descriptions and meaning of events so that new insights can be drawn from such findings (Burns 2000).

The two rounds of empirical investigations were performed during this study process as follows:

2.4.1 Conduct and findings of the exploratory interviews

During Phase 3, exploratory, semi-structured interviews were relied upon to pre-test the preliminary model of a max VCMF and its IT-based management system. The latter was used to explore an assumption that the degree of virtuality of a construction management firm can be measured in terms of its virtual management performance level with the help of an indicative, IT-based management system. The exploratory interviews were conducted with the firm managers and the project managers in the **six case companies**. These companies were selected from among the building contracting and CM consulting practices in Finland. The **threefold purpose of the exploratory interviews** was (i) to detect the matches/mismatches and convergence/ divergence of the characteristics of the case companies' management systems in comparison with the characteristics of the preliminary management system of a VCMF, (ii) to detect the extent to which these case companies' management systems are IT-based/enabled and, thus, to assess their virtual performance, and (iii) to compare the case companies' management performance, elaborated upon by the interviewees themselves, with each other and a VCMF's symbolic management performance in terms of its management subsystems.

A formal Likert scale was not employed for these exploratory assessments. Instead, the researcher used **three qualitative representations**, i.e. perfect-match, medium-match and no-match for the pair-wise comparisons between the management system of each case company and that of a VCMF. A perfect match indicates that the characteristics of a case company's management system match those of a VCMF's characteristics. A medium match indicates that a case company's management system has a partial correspondence to that of a VCMF. No match indicates that there is no correspondence whatsoever between a case company's management system and that of a VCMF. The interviews were conducted through the use of a questionnaire with a set of statements. Each statement described one of the characteristics of each of the management subsystems of a VCMF and a question to detect a method/form of performance (e.g. How does your company perform ….).

On the one hand, the **analysis of the exploratory interview data** revealed that some case companies had an organisational structure that was similar to that of a VCMF. However, these case companies were not

performing all of their management functions according to the system of a VCMF. There was one traditional case company that did perform its management functions in a virtual or semi-virtual way/manner, although its management system did not match that of a VCMF at all. This case company's management had no intention of becoming a virtual organisation.

These findings from the exploratory interviews enabled the researcher in part to proceed with the final model design as Phase 4 of the study process (see p. 10).

2.4.2 Benchmarking and the reliance on the theme interviews

During Phase 5, for the benchmarking process, the theme interviews were conducted by using the pre-formulated questionnaires, based on the Finnish CM concepts, to investigate the applicability of the three-dimensional virtuality model in terms of the final VCMF model as a tool for measuring the degrees of virtuality in Finland-based CM firms. The same six case companies that were dealt with during the exploratory interviews were approached again during this main round of the theme interviews. In addition, the researcher perceived that the four new case companies were needed in order to shed a more versatile light on the emerging virtuality in the Finnish context in focus. The conduct of the theme interviews and the results of the benchmarking process are reported upon in more detail in Chapter 5.

2.5 Exclusion of alternative empirical research methods

In general, case study research is common when focusing on understanding dynamics within single settings. Case studies are considered to be an empirical enquiry that investigates a contemporary phenomenon within its real life context when boundaries between a phenomenon and a context are not clearly evident and in which multiple sources of evidence are used (Yin 2003). In this study, the **case study research** was not valid because it would have been very difficult, if not impossible, (i) to design a preliminary VCMF model based on theorising from cases (Eisenhardt 1989) when such virtual reality has not (yet) existed in the Finnish context, or (ii) to investigate the applicability of the final VCMF model among eligible companies using an in-depth case study approach when the required depths were (still) non-existent.

Alternative research strategies such as surveys and archival analyses were also considered invalid in this study. **Surveys** usually reflect each respondent's subjective observation of a phenomenon without a systematic analysis of its roots. Novel findings are extremely rare when fully structured surveys are relied upon (Fowler and Floyd 1995). When this study aimed at gaining a deeper understanding of virtuality as an emerging phenomenon, surveys could not have provided sufficient results. In the same vein, **archival analyses** were excluded because the researcher could not identify a single company, within the Finnish context of this study, where data on virtualisation would have been recorded. Virtuality as a principle of organising has not been acknowledged on organisational and project levels.

Quantitative and statistical research methods were not valid in this study either. This was because quantitative research approaches imply a reliance on finding relevant answers from a large amount of information gathered over a wide area, mainly numerical data (Bryman & Cramer 1995). When this study was geared to address the focal CM field and there were no Finnish companies with a history in virtuality mainly for the reasons stated above, quantitative research methods were deemed not valid in the case of this study.

3. REVIEW OF THE SELECTED LITERATURE ON VIRTUALISATION AND CONSTRUCTION MANAGEMENT

In this chapter, results from the review of **selected, foundational references** on virtuality, collaboration, VOs, drivers behind emerging VO concepts and enabling IT are presented in order to provide a generic understanding and theoretical bases for the contextual model design. In addition, CM in general and CM companies in the Finnish construction industry are characterised in order to describe the focal context for the model design task.

3.1 Generic virtuality and factors driving towards virtualization

3.1.1 Virtuality and organisations

The **essence of virtuality** in relation to organisations can be distinguished with the help of **four founding concepts** as follows. (i) Virtual means unreal, looking real or virtual reality. A VO appears to be a real (traditional) company to externals but in reality a VO does not exist, it is only a conglomerate of independent members. (ii) Supported by ICT, virtual means immaterial. It is something that does not exist in a concrete form, it is only created by data. For example, a virtual shopping mall only exists on the Internet. A virtual office does not exist in physical terms, employees work from home and are connected to each other by ICT. Similarly, virtual products (e.g. software and newspapers on the Internet) do not have any physical appearance, they exist only because of ICT. (iii) Virtual means potentially present, an organisation does not really exist but it would have a possibility to exist; i.e. as soon as a need is spotted, a corresponding operating unit will be configured. A virtual cluster represents a potential possibility to format any required network configuration. (iv) Virtual means existing but changing, like a dynamic and

progressive network. An organisational unit is existing but a composition of members is temporary, an organisation that is constantly reconfiguring itself. There are virtual corporations at the company level and virtual teams on the workers' level (Hedberg et al. 1997, Franke 2001).

Virtualisation is driven by many **megatrends** (Skyrme, 1999) such as the globalisation of markets and resources (companies can more easily sell products worldwide and make use of world-class expertise), networking and interdependence (new collaborative organising gives access to resources, flexibility and responsiveness) and Internet revolution (redefined ways to conduct businesses, work and services are carried out over a distance, information and knowledge-based products and services are marketed and even delivered virtually).

3.1.2 Global business environment

A global business environment involves **a huge, complex, uncertain network** in which single organisations are embedded and interrelated. In general, globalisation, together with changes in market structures, consumer needs and technology innovations are also the key factors pushing for and causing changes in organisational structures (Bauer & Köszegi 2003, Saabeel 2002). VOs are assumed to lower complexity and uncertainty by cooperating with other organisations in a network that operates as a single organisation (Saabeel et al. 2002). The **two major forces** driving towards virtual organising are characterised as follows. (1) Changing market conditions, especially changes in demand for specialised products, lead to broader ranges. Individualisation means that companies tailor products and services according to individual wishes and, thus, increase complexity across organisational functions. At the same time, shorter product cycles imply more investments in R&D, production and sales as well as internationalising markets and globalising competition. (2) The fast development of enabling ICT improves speed, quality and transactions (Franke 2001).

This changing business understanding instigates organisational change, decreased complexity and increased flexibility within companies. Thus, many companies aim at **optimum value creation** and employ **core competence strategies**, i.e. they concentrate on what they do best, specialise in certain areas, develop core competencies and integrate and embed core competencies within value chains. All this implies virtual

organising: (i) A VO enables member companies to achieve higher performance by making use of networked resource bases by concentrating on and developing their own core competencies as well as giving up standard competencies. (ii) A dynamic and temporary corporation is formed where each member is chosen because it brings something unique. Best-of-class teams create additional core competencies on a higher level that, in turn, enable the creation of specialised products and performance with excellence among competitors (Barnatt 1996, Camarinha-Matos et al. 2005).

3.1.3 Needs for new VO concepts

The acquisition and in-house development of all required resources and competencies can be both time consuming and costly for organisations acting on their own in order to exploit opportunities in the face of turbulent business environments. Instead, VOs are capable of rapid and adaptable responses to **turbulent, changing business environments**. VOs combine one or several existing organisational structures and capabilities into new organisational competencies. Collaborative VOs are formed to exploit business opportunities. Members contribute different knowledge, skills and resources (Saabeel et al. 2002).

Internationalisation is increasing competition across national boundaries. Companies operating in their home markets face new foreign competitors. The latter are seeking to improve their economies of scale by conquering export markets and gaining local market shares. In turn, local companies can improve their competitiveness and defend their positions in home markets by forming VOs, specialising and participating in best value chains. Members can share costs, risks and access to one another's markets. Members may involve small and medium-sized enterprises (SMEs). Cooperation with other members in VOs enables each of them to project a joint appearance and penetrate new international markets (Camarinha-Matos & Afsarmanesh 2004, Camarinha-Matos et al. 2005).

A VO has its roots in the paradigm of **network organisations** (Franke 2001). A VO as a normative net of organisational principles is applicable to (a) the internal organising within defined organisational boundaries (an intra-organisational perspective) and (b) the external configuration of independent actors across organisational boundaries (an inter-organisational perspective). A VO is a temporary, dynamic network of

legally independent and to varying degrees economically independent companies. Each member company contributes its set of specific resources to a high economic performance of a VO (Skyrme 1999, Scholz 2000, Camarinha-Matos & Afsarmanesh 2004).

3.1.4 Strategy of virtual organising

A VO is not organised as a distinct functional, divisional or matrix structure. Virtualness is applicable to old companies and new entrants alike in fast changing high-technology marketplaces. **Virtual organising** can be defined as "*a strategic approach that is focused on creating, nurturing, and deploying key intellectual and knowledge assets while sourcing tangible, physical assets in a complex network of relationships and supported by a powerful, integrated IT platform"*. In turn, **process outsourcing** can be defined as "*the delegation of one or more business processes to an external provider who then owns, manages and administers the selected processes based on measurable metrics"*. It is expected that many companies will recognise the criticality of business process outsourcing when processes become more standardised and markets mature with more stable participants. At the same time, more specialist companies emerge as members in reconfigured business networks (Venkatraman & Henderson 1998: 33-48).

From among the relevant literature, Scholz's (2000) three vectors are selected and herein reviewed as an **exemplary, vector (dimensional) model** that companies can apply to the design of their strategies of virtualisation. A global, accessible, collaborative IT infrastructure can be deployed. The three vectors of encounter, sourcing and expertise are supported by a powerful, integrated IT platform as follows. **(1) A customer interaction vector (virtual encounter)** deals with new challenges and opportunities for company-to-customer interaction. IT allows customers to remotely experience products and services, actively participate in dynamic customisation and create mutually reinforcing communication via three stages as follows: (a) The remote experiencing of products and services through a marketing infrastructure and a website implies that every company should assess how its products and services can be experienced virtually. (b) The dynamic modularisation and customisation of products and services enables a high functionality to be delivered. Marketing is shifted from an inside-out to an outside-in perspective. Tasks are partitioned into independent modules that function

together within an overall architecture. Intelligent websites learn the tastes of visitors (clients) and deliver dynamic personalised information. An automated, collaborative filtering process lets users receive real-time, personalised listings for items in product and service catalogues. Organisations and processes are geared to deliver such products and services on a dynamic and adaptive basis. (c) Electronic customer communities are emerging as information-gathering and information-disseminating conduits.

(2) An asset configuration vector (virtual sourcing) involves the creation and deployment of intellectual and intangible assets, continuous reconfiguration and assembly of critical capabilities as well as the sourcing of tangible, physical assets from a complex business network. IT allows the efficient sourcing of standard modules and creates opportunities for process outsourcing. Assets are being (re)configured through three stages as follows. (i) Choice of assets, standard modules and components that will be obtained from outside without a loss of competitive advantage. Companies adapt sourcing logics to evolving market conditions and changes in asset criticality. (ii) Determination of process interdependence across organisational boundaries enables to contract external specialists in order to carry out information-intensive business processes without loss of control. (iii) Establishment of a vibrant, dynamic resource network involves the selection of companies with their critical, complementary capabilities. A VO becomes a portfolio of capabilities and relationships. The positioning of a VO in the marketplace is a driver of competitive advantage, each member balances its leadership position relative to one set of resources. The distinction between competition and cooperation is becoming blurred when every member positions itself within a resource network and simultaneously plays competitive and cooperative roles. Knowing where and how to add value underlies this new game of virtual organising (the logic of combining cooperation and competition).

(3) A knowledge leverage vector (virtual expertise) involves information-based organisations with knowledge specialists. Knowledge and intellectual assets are basic economic resources. Overhead costs are lowered, the execution of strategies is supported and learning rates of responsive employees are substantially increased through the exploitation of knowledge assets. Knowledge can be leveraged via three stages as follows: (i) Harnessing of work unit expertise and designing of work redistribution across time and distance are ensured through integrated control systems. Groupware, videoconferencing and intranets facilitate

team-level coordination and exchange of information and knowledge. Teams develop routines for sharing knowledge and expertise. (ii) Harnessing of collective expertise is designed and executed across rather than within work units. (iii) Leveraging of a community's professional expertise is enabled, even with customers and a broader professional community. VOs can retain a core of experts while electronically contracting other skills for the virtual leveraging of expertise in professional networks.

3.2 Collaborative relationships and virtualisation

The emerging paradigm of networked (collaborative) organisations involves supply chains, outsourcing practices and autonomous teams (human collaboration). Whenever a business opportunity arises, interested companies can create **a dynamic, long-lasting VO,** establish a base network and form an ecosystem. Members are driven by willingness to cooperate on common business practices and infrastructures as well as to build trust incrementally. In turn, human collaborative relationships, especially those based on professional interests and motivations, lead to another form of networked organisation called **professional virtual communities**. Such communities are the most relevant elements for keeping a business ecosystem alive and for launching and operating dynamic VOs (Camarinha-Matos & Afsarmanesh 2004a).

3.2.1 Six basic concepts in virtual organizing

The emergence of networked organisations is coupled with the generation of new paradigms and concepts. Six interrelated concepts are herein compiled and introduced as follows. A **virtual enterprise** is a temporary alliance of enterprises that come together to share skills, core competencies or resources in order to better respond to business opportunities. Cooperation is supported by computer networks. An **extended enterprise** is an organisation in which a dominant enterprise “extends” its boundaries to all or some of its suppliers. An extended enterprise can be seen as a particular case of a virtual enterprise. A **VO** comprises a set of (legally) independent organisations that share resources and skills to achieve its mission/goals, supported by a computer network. Members provide the outside world with functionality and a set of services as if they represent a single organisation together. A virtual enterprise is therefore a particular type of VO. A **dynamic VO** refers to a VO that is established in

order to respond to a competitive market opportunity. It has a short life cycle. It dissolves when the short-term purpose is accomplished (Camarinha-Matos et al. 2005, Franke 2001). A **virtual breeding environment** (VBE) represents an association or a pool of organisations and supporting institutions that have both the potential and the will to cooperate with each other through a long-term cooperation agreement. This base enables cooperation agreements, common infrastructures and mutual trust. The same elements are necessary for the creation of a new VE/VO. Thus, a VBE is also known as a source network where entities are prepared for cooperation in case a specific opportunity arises. In turn, such a network is considered a pre-condition for an effective establishment of dynamic VOs. A **professional virtual community** (PVC) is a combination of a virtual community and a professional community. Virtual communities are the social systems of networks of individuals who use computers. Professional communities are the networks of people connected with professional values and behaviours. When professional communities adopt computer networks and most of practices of virtual communities, professional virtual communities emerge (Camarinha-Matos & Afsarmanesh 2004a, Camarinha-Matos & Afsarmanesh 2005).

3.2.2 Network Organisations

Networks are the organisational form of the information age (de Man 2004). Networks are organised to increase access to information and to enhance the use of information. A **network organisation** is a form of collaboration designed to facilitate economic exchange and provide an environment for interaction between people (social exchange). Economic actors sacrifice some of their own preferences in pursuit of collective goals. The **five key organisational principles** of networking are as follows. (i) A unifying purpose, i.e. common views, values and goals hold a network together. A shared focus on desired results sustains synchronised operations and network directionality. (ii) Each member, e.g. a company or an individual, continues to sustain its independent existence while benefiting from being part of the whole. (iii) Voluntary links are created when members join forces. (iv) Multiple leaders allow for a greater resilience as each person or group has something unique to contribute. (v) Integrated, multilevel organisations operate on many relevant levels and enhance cooperation between organisations, departments and people (Fleisch & Österle 2000, Franke 2001).

Network organisations can be viewed from intra-organisational and inter-organisational perspectives. An **intra-organisational network** is a collection of individuals and sub-units within the same organisational boundaries. An **inter-organisational network** is a collection of more or less independent economic actors, such as companies. The three inter-organisational network types are as follows: (i) **Internal networks** are loose associations of assets and business units contained within a single company that subject themselves to market forces. Such business units consist of autonomous groups and teams. Management tasks are often decentralised to autonomous teams. Employees are available in many places within an enabling, flexible structure. (ii) **Stable networks** consist of companies engaged in long-term relationships with external suppliers who bring expertise into a parent company. Participants are organised around a single large company as in the case of the Japanese car manufacturing. A main organisation (often a core member) contracts out non-core competencies to several committed suppliers. (iii) **Dynamic networks** are more temporary, flexible alliances of companies with key skills, usually organised around a leading or brokering company. Each unit tends to be independent, and they collaborate on a specific project or opportunity. A dynamic network cooperates on a large scale basis with other organisations based on opportunism. Relationships are temporary. Cooperation takes place only when a certain market incentive occurs (Franke 2001, Camarinha-Matos & Afsarmanesh 2004).

3.2.3 Strategy of Outsourcing

There are a number of reasons why an organisation should consider outsourcing one or more of its functions as follows: (i) A company **focuses on core functions** that are key to its survival and distributes other functions among a group of suppliers who are capable of performing them. (ii) A company **focuses on strategy** by giving a tactical part of each manager's job to suppliers, which allows a management team to concentrate on strategy issues. (iii) A company with poor competencies solves such an **inadequacy problem** by outsourcing a problematic function to a specialised supplier. (iv) A company **reduces costs** by outsourcing and using more effective suppliers who may centralise the work of several companies at one location and/or buy materials or supplies at lower costs by using volume purchasing. (v) A company **avoids major investments** by outsourcing a low-efficiency function to an experienced supplier. (vi) A company **improves flexibility** by outsourcing and thus

eliminating fixed costs of internal staff, as such an external supplier will only be paid for actual work done. (vii) A company **enhances credibility** by using outsourcing as a marketing tool, i.e. customers are assured of continuous high-quality services by relying on well-known suppliers. (viii) A company implements a **strategic reorganisation** where outsourcing can be used as a main tool in the transition to a new company structure (Bragg 2006: 154-185).

3.3 Generic VO

3.3.1 Three approaches to a VO

In generic literature, **three main approaches** can be distinguished for the conceptualisation of a VO as follows. (1) A VO is essentially an **electronic, online organisation**. Such organisations (e.g. amazon.com) exist in and exploit opportunities offered by the World Wide Web (www) and cyberspace.

(2) A VO is an **organisational structure** where entities come together and collaborate in order to share competencies, skills, knowledge and other resources for the purpose of producing a particular service or good or taking advantage of a particular opportunity. A typical definition is: "A *VO is composed of several business members sharing costs and resources for the purpose of producing a product or service, it can be temporary or it can be permanent. Each partner contributes complementary resources that reflect its strengths, and determines its role in the virtual corporation."* (Marshall et al. 2001: 171-192). In this approach, there are two structural conditions for a VO to exist, i.e. (i) a spatially dispersed organisation, in at least two locations (Marshall et al. 2001) and (ii) the electronic linking of a production process based on IT (Travica 1997). Accordingly, a VO refers to "*a temporary or permanent collection of geographically dispersed individuals, groups, organisational units - which do or do not belong to the same organisation - or an entire organisation that depends on the electronic linking in order to complete its production process"* (Travica 1997). IT plays a central role in the formation of a VO. Typically, Travica's (1997) research model for empirically investigating VOs contains nine interrelated aspects with IT being at the centre (Figure 2). Members learn how to use IT and about each other's skills, expertise, working habits and so on. IT supports information-rich production and communication between workers. Each member adjusts to

a dispersed, organisational context. VOs may emerge as productive business systems with little or no dedicated physical structures, bureaucracy, employment structures or resource bases (Barnatt 1996).

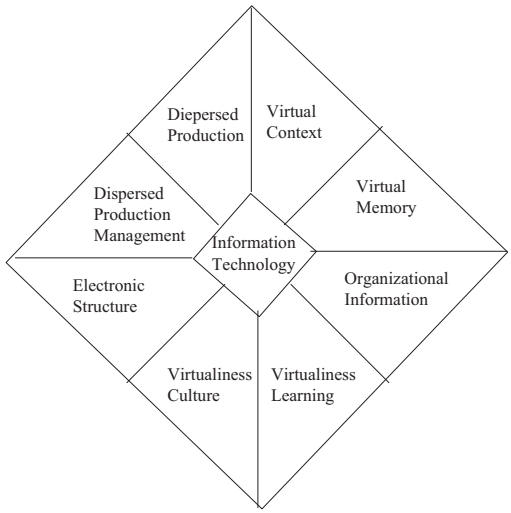

Figure 2. Research model of a VO (Travica 1997).

(3) A VO is a **mixture of the two previous approaches**, i.e. actors move interchangeably between a VO as an online organisation and a VO as a transient network of people, ideas, competencies and resources which come together for a particular purpose.

3.3.2 Attributes of a VO

Within the literature, VOs have been characterised with an increasing set of 16 attributes that ensure both flexibility and effectiveness. These attributes are as follows (Barnatt 1996, Skyrme 1999, Marshall et al. 2001, Scholz 2000, Franke 20011, Saabeel et al. 2002, Camarinha-Matos & Afsarmanesh 2005):

- A dynamic network involves cooperating organisations that can enter and leave at any time.
- A new market opportunity triggers companies to band together.
- Greater benefits in terms of increased market shares, productivity, revenues and profitability are achieved by membership in a VO in comparison with those benefits that potential members can grasp alone.

- Semi-stable relations between members preserve cooperation only for the exploitation of a specific opportunity.
- A geographically dispersed structure enables high flexibility and effectiveness.
- IT is a key supporting factor underlying an effective dispersed structure and the linking of widespread members to work together.
- A shared vision and purpose are the glue that holds members and people together in order to accomplish the desired results. Thereafter, VOs often dissolve.
- A shared ownership means that every independent member has its own interests and some parts of a VO can have separate owners. When a particular member has achieved its goal or finds out that the achievement is not possible, this member can step out.
- Core competencies are a main criterion for membership within a best-of-everything VO. When the core competencies of each member are combined, this leads to synergies and flexible responses to customer needs.
- Innovative organisational culture, products and services are a condition of success when a VO responds to market-based incentives.
- The flexible satisfaction of customers' particular needs and wishes is in part based on virtual product development together with customers and in part enabled by mass-customisation and organisational learning (OL).
- Shared leadership means that every member controls its own resources but not automatically the resources of a VO.
- Small-sized members and the parts of large members are flexible and fast-moving enough for going after a business opportunity.
- Shared risks are accepted among members to the extent that they correspond to degrees of activity interdependency within a VO. When market-based incentives become greater, risk taking increases.
- A high level of trust is an enabling condition within a VO. Trust replaces rules, procedures and policies that dictate behaviour within traditional organisations. The fate of each member is dependent on the fate of other members, respectively (a co-destiny). Trust drives an open sharing of information and knowledge among members.
- Shared loyalty means that the employees of every member also identify themselves with a VO. High degrees of shared loyalty are enabled by a VO's open culture.

3.3.3 Types of VO

The two typologies of a VO were selected from among many alternative groupings. It seems that these reviewed typologies also cover the emerging types of virtualised companies in the focal CM context.

Palmer & Spier (1997) have differentiated four distinct types of VO, based on scope of work, projected time spent in virtual work, project types and range of involvement and number of personnel involved, as presented below (Table 1). (1) **Permanent VOs** are designed, from their inception, to bring together market players and respond to opportunities for both improved revenue-generating activities and cost savings. Virtuality is incorporated in the management of an organisation, teams, operations and tasks. (2) **Virtual teams** and tasks are generated through the internal use of virtual concepts in a variety of organisations and their business units, functions and processes. (3) **Virtual projects** are formed as alliances or consortia in order to bring complementary organisations together in order to meet market opportunities. Examples include new business alliances, industry trade associations, cooperative activities and buying consortia. (4) **Temporary VOs** are the extensions of virtual project designs and they are established in order to take on multiple projects and develop responses to market opportunities. When a particular market opportunity ends, a coupled, temporary VO is terminated, too. It is an initial VO model involving virtual management, tasks and teams.

Table 1. Exemplary typology of a VO (Palmer and Spier 1997: 5).

	Virtual Teams	Virtual Projects	Temporary virtual organisation	Permanent virtual organisation
Range of involvement	Internal to organisational function or department unit	Across functions and organisations	Across organisations	Across organisations
Membership	Small, local	Intermediate	Typically larger	Typically smaller, but scalable
Mission	Teams on specific, ongoing tasks	Multiple organisational representatives working on specific projects	Multiple functions Responding to a Market opportunity	All functions and full functionality as a working organisation
Length of project	Membership varies but form is permanent	Temporary	Temporary	Permanent
Use of IT	Connectivity, sharing embedded knowledge, (groupware, email)	Responsibility of Shared data (databases, group-ware	Shared infrastructure (Groupware, WANs, Remote computing)	Channel for Marketing and Distribution, replacing Physical infrastructure (Web intranet)

In turn, Marshall et al. (2011) have specified the four alliance models of a VO based on an adopted structure and a manner in which a VO positions itself within its environment as follows: (i) A **co-alliance model** of a VO is based on shared membership, i.e. members form a consortium and each member makes fairly equal contributions in terms of resources, competencies, skills and knowledge. A composition of an opportunistic consortium changes to reflect opportunities or the changing core competencies of each member. Mutual convenience takes place on a project-by-project basis. The shared, realised effectiveness and benefits encourage members to reassemble intermittently when suitable opportunities present themselves. (ii) A **star-alliance model** of a VO is a coordinated network with a leading core surrounded by interconnected satellite members within the same industry. A dominant leader directs and dictates the supply of competencies, expertise, knowledge and resources to members. The achievement of benefits of a VO is closely linked to that of a lead member. (iii) A **value-alliance model** of a VO brings together a range of interrelated products, services and facilities that are based on an industry-specific value (supply) chain. Collaborative members are able to

operate as a single VO towards end consumers. (iv) A **market-alliance model** of a VO involves organisations that coordinate the manufacturing, marketing, selling and distribution of a diverse but coherent set of products and services. It is likely that several value chains are interconnected and form a marketplace or a community from the perspective of end customers.

3.3.4 Measurement of degrees of virtuality

The measurement of a company's virtuality requires an instrument that is applicable to measuring both the characteristics of collaborating entities and those of their relationships. Because many traditional organisational forms also exhibit at least some of the characteristics of a VO, a binary classification of virtual organisations versus non-virtual ones is not valid. Instead, **a valid method involves the measurement of the gradual virtualisation of a company**. The more virtual (structural and relational) characteristics a company exhibits, the higher its degree of virtuality. Developing an instrument for measuring the degrees of virtualisation enables (a) the analysis of companies' virtual organisational structure development over time, via several stages, and the coupling of such internal, virtual degrees with environmental contingencies in order to provide insights into a theory of co-evolution of companies and environments; (b) related to the degrees of virtualisation to the levels of organisational performance, in order to empirically test whether virtual structures are performing better than alternative organisational designs in dynamic environments; and (c) the classification of organisations according to their degrees of virtualisation in order to determine their current positions along the development path towards a VO and to identify potential for future development (Bauer & Köszegi 2003).

Within the literature, **three distinct approaches** could be identified in order to determine the degrees of virtuality of any organisation as follows. First, a predetermined, ICT-driven path involves stages from a non-virtual organisation to a VO, e.g. those stages defined by Venkatraman & Henderson (1998). Each company is classified according to its actual stage of development and an associated degree of virtuality. Second, an ideal, virtual company exhibits predetermined characteristics as a reference for measuring degrees of virtuality, without any path dependency, e.g. Scholz's (1998, 2000) virtual cube model, which captures the statics and dynamics of a virtual structure. Third, the actual degrees of the gradual virtualisation

of companies and their organisations can be measured along **four structural dimensions** as follows (Bauer & Köszefi 2003):

A. Modularity and heterogeneity encompasses a variety of satisfiers (i.e. modules) with specific competencies and strengths for meeting diverging customer needs. Each satisfier develops its core competence to optimally meet a specific requirement. A flexible and dynamic combination of core competencies related to unique value chains gives a company an opportunity to achieve competitive advantages by increasing resources and know-how virtually. A virtual company (VC) is considered to be a best-of-everything organisation. Synergies among competing members leverage the core competencies of similar satisfiers. Besides increased capacity (virtual size) goals, a VC aims at attaining other goals such as quality, flexibility and time. There are two initial indicators, i.e. virtual value creation measures the extent of modularisation of value creating processes inside companies (A1), whilst a focus on core competencies measures the extent to which companies focus on their core competencies (A2).

B. A **temporary and loosely-coupled network** of independent member companies is configured to meet targeted customer requirements. This dynamic structure of a VC changes with customer requirements. The prerequisites for inter-organisational flexibility are structural and cultural relationships between network members (Saabeel et al. 2002). There are three initial indicators, i.e. the general characteristics of a network includes duration of memberships, configuration of cooperation, appearance towards customers, etc. (B1). Independence measures a degree of horizontal and vertical independence between members in a network (B2). Formal and contractual commitments between members measure the extent to which contracts, rules and regulations are used (B3).

C. Integration involves several mechanisms. Externally, market-based mechanisms are required for VCs. Price coordinates markets. Internally, authority coordinates hierarchies. Trust between members has a fundamental impact on the success of a VC. Trust is a mechanism which is used to govern and coordinate an exchange of relationships that are characterised by high uncertainty and high interdependence between transaction members. In a trust-based system, behaviour is guided by shared norms and self-control is adopted. An initial indicator involves trust as a coordination mechanism that measures the general atmosphere, trust and fairness inside a network (C1).

D. Information and communication technologies (ICT) enable the integration of a VC on social and technical levels. ICT guarantees an efficient coordination of activities along value-adding processes. An initial indicator involves the implementation of ICT that measures the extent of reliance on communication systems and that of the use of computer systems for facilitating cooperation inside a VC (D1).

In principle, the concepts of gradual virtualisation can be extended to measure and compare the adoption of virtual structures in different industries as part of industry development.

3.3.5 Dynamics within a VO

In the literature, a VO has been defined from structural and procedural perspectives. From a **structural point of view**, a purposeful system is composed of a set of interrelated elements within a VO, i.e. actors (such as organisations, individuals), resources (such as core competencies) and activities. They are interrelated by control structures, interdependencies and exchange relations. The characteristics of elements and the nature of relationships between elements define the properties of a system. Properties may involve temporariness, opportunism, use of ICT, dynamism, flexibility, continuous change, hybrids, reformation, etc. Relationships between actors are characterised with (i) purpose as an incentive for creating and holding a new temporary organisation together, (ii) connectivity as a leverage of shared assets, resources as well as intellectual and knowledge assets, (iii) a boundary between the members of a VO and external actors in the absence of clear physical and legal borderlines, and (iv) ICT as an enabling factor (Saabeel et al. 2002).

From a **process perspective**, the focus is on the way a VO can account for changes in its environment and renew itself. A basic process consists of the formation, operations and termination of a VO. Dynamics emphasise the mechanisms and processes of creation and reconfiguration within a VO. Dynamic changes in customer requirements and the availability of products and services force the management of a VO to adopt the flexible principles of organising (Bauer & Köszegi 2003). A VO continuously repositions itself in a changing environment. New business processes are designed and implemented. Typically, Katzy's (1998) **conceptual model** explains the life cycles of VOs via its three constructs, i.e. (i) a **network** consists of pre-existing industrial structures, relationships between members, resources,

routines and processes, (ii) a **virtual (dynamic) operation** is a process that combines competencies and resources for a period that is needed in order to realise value to customers, and (iii) **value** drives a VO to restructure. The changing process of a VO links the design of a network, the restructuring of dynamic operations and the creation of new business opportunities, respectively (Figure 3).

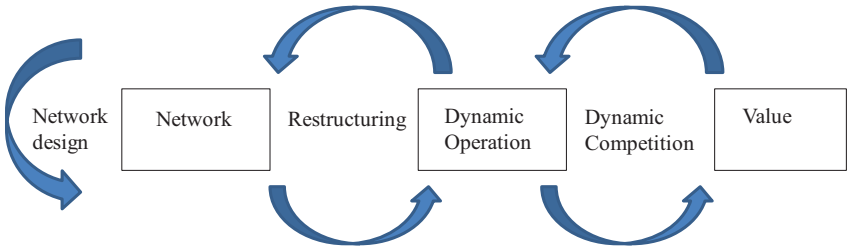

Figure 3. Conceptual model of the design and implementation of VOs (Katzy 1998).

In turn, Saabeel et al. (2002:6) have defined **12 dimensions** along which the structures of VOs can be redesigned and reconfigured. These dimensions have been compiled in Table 2.

Table 2. Dimensions of the structure of a VO (Saabeel et al. 2002: 6).

Term	Definition
Goal-specificity	Activities and interactions of participants are co-ordinated to achieve specific goals. Goals are specific to the extent that they are explicit, are clearly defined, and provide unambiguous criteria for selecting among alternative activities (Scott, 1998, p 25)
Formalisation	The co-operation among participants is conscious and deliberate; the structure of relations is made explicit and can be deliberately constructed and reconstructed. A structure is formalised to the extent that the rules governing behaviour are precisely and exlicitly formulated and to the extent that roles and role relations are prescribed independently (Scott, 1998, p.25)
Modularity	The extent to which the virtual organisation is based on integrated, customer-oriented processes composed of relatively small, manageable units decentralised decision-making competence and responsibilities. These are units, consisting of assigness, which can belong to different legal institutions (Wigand et al., 1997, pp.161, 342)
Hetrogeneity	The extent to which the components of organisation have different performance profiles with regard to their strengths and competencies (Wigand at al., 1997, p.342
Time and spatial dispersion	The extent to which the components of the organisation are dipersed in place and time (Wigand et al.,1997,p343
Purpose	The objective that provides the incentive for creating the new organisation and which serves as the cohesive force to hold the virtual organisation components at least temporary together (Shao et al., 1998)
Connectivity	The creation of unity or linkage through structural change, breaking of constraints, or overcoming of previously existing barriers (Shao et al., 1998)
Boundary	An indication for the separation of those who are part of the virtual organisation and those who are not, in the absence of clearly visible physical border lines (Shao et al., 1998)
Technology	The enabling factor that allows the breakthrough and makes the virtual form possible (Shao et al., 1998)
Complexity or diversity	The number of different items or elements that must be dealt with simultaneously by the organisation (Scott, 1998, pp.229-230)
Uncertainty or unpredictability	The variability of the items or elements upon which work is performed or the extent to which it is possible to predict their behaviour in advance (Scott,1998,pp.229-230)
Interdependence	The extentto which the items or elements upon which work is performed or the work processes themselves are interrelated so that changes in the state of one element affect the state of the others (Scott,1998,pp.229-230)

1997,p.342

3.3.6 Life cycle of a VO

A VO can be seen as a process, i.e. a goal-producing behaviour that is composed of events that constitute changes in the structural properties of a system or its environment (Saabeel et al. 2002).
In the literature, change over time is divided into broad phases. Each phase consists of a group of activities aimed at a similar goal. Each phase is also accompanied by challenges and tasks. A transition between phases may be rough or smooth. Certain tasks, decision processes and management activities are proposed in order to initiate and support change (e.g. Zimmermann 1996/1997, Franke 2001, Saabeel et al. 2002).

Strader et al.'s (1998) exemplary **model of a life cycle of a VO** consists of four phases, i.e. identification (member search), formation (contracting), operation and termination (dissolution and reconfiguration) (Figure 4). In each phase, there are two or more decision processes. In Phase 1, **members** are sought after e.g. via Internet-based catalogues where companies present their core competencies. A new profession, an information broker (Net-broker) is emerging. It helps companies find the right members and it may take over tasks within a VO. Typically, a lead company maps potential members against a set of distinct membership criteria. This phase ends once a best market opportunity has been selected for a VO's pursuit (Franke 2001).

In Phase 2, an actual VO is **formed through a membership** of selected companies. Members negotiate and draft a framework of agreements on cooperation, which includes rules for the division of work, the assignment of resources, operational procedures and a necessary infrastructure for cooperation. Members can proceed with the determination of a mean between over-regulation (reduces flexibility) and under-regulation (increases coordination costs).

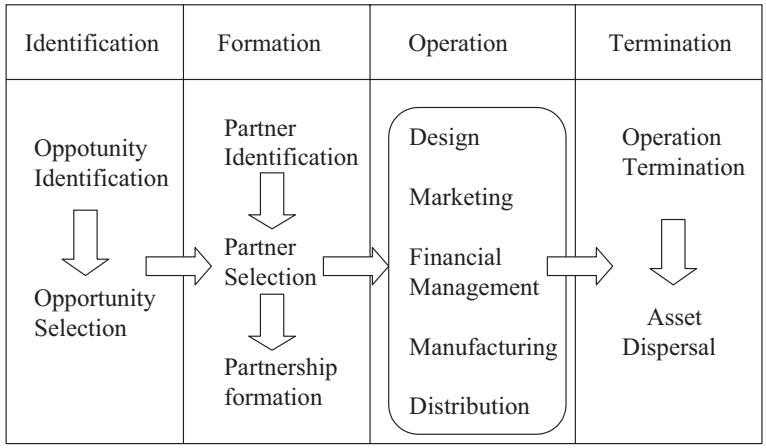

Figure 4. Life cycle model of a VO (Strader et al. 1998).

In Phase 3, a VO plans and starts its **operations** in the areas of management, design, marketing, financing, manufacturing and distribution. A focus is on the coordination of production. Prior agreements are reviewed against operational decisions. Each member undergoes a reorganisation in order to maintain a fit with other members. In Phase 4, a VO is **terminated** after it has exploited a market opportunity. An actual configuration may be changed or a VO is completely dissolved (Franke 2001).

3.3.7 Working mechanisms of a VO

Many working mechanisms of a VO can be explained by combining the structural and process views (e.g. Franke 2001). Saabeel et al.'s (2002) **exemplary, integrated model towards a VO** consists of three layers representing the structural elements, while transition between the layers represents the process elements (Figure 5).

On the first layer, a universe of modules represents all organisations of a particular industry or economy. Modules represent actors with their different objectives, strategies, competencies and resources. An actor can be an organisation, a group or an individual. Actors are very loosely related. A universe of modules is characterised by complexity, uncertainty and interdependence. This is where the formation process of a VO starts (Saabeel et al. 2002).

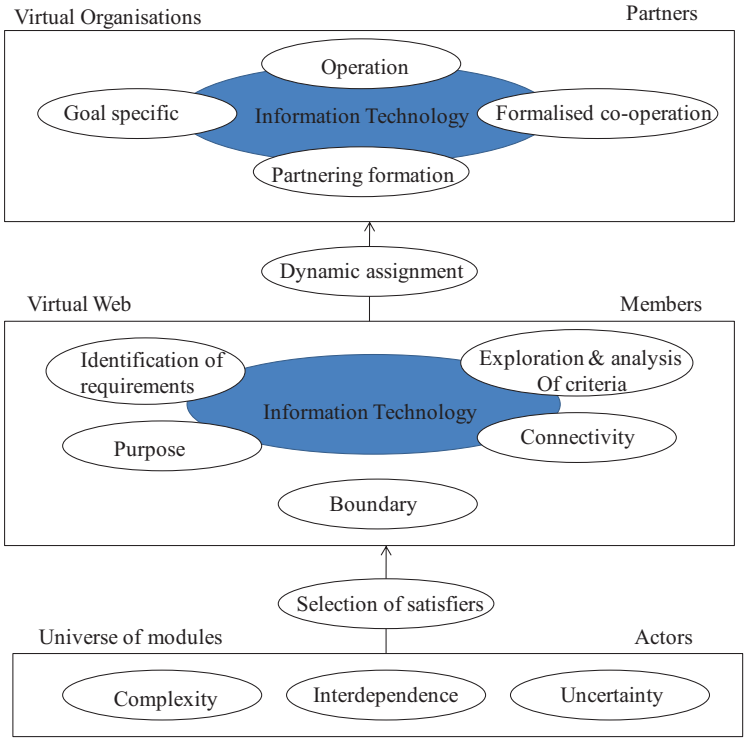

Figure 5. Integrated model towards a VO (Saabeel et al. 2002: 12).

On the second layer, a virtual web is an open-ended collection of pre-qualified members that agree upon forming a pool of members of a particular VO. Actors organise themselves into dynamic webs in order to overcome difficulties in complexity, interdependency and uncertainty. Potential members are being selected from the universe of modules. In a web, relationships are characterised by structural elements, i.e. purpose, connectivity, boundary and ICT. Members agree on a purpose in terms of products and markets to be served, based on a common view on market opportunities and expected customer value that members can create by sharing their complementary competencies and resources. Connectivity indicates the extent to which core competencies of members are complementary and the extent to which cooperation in a VO adds value (compared with no cooperation at all). Agreements define the boundaries of a web in terms of membership (Bauer & Köszegi 2003, Saabeel et al. 2002).

A selection process aims at identifying companies that can have complementary competencies and evaluating their capabilities to cooperate in a VO such as organisations consisting of modular units (relatively small

but manageable units with decentralised decision-making, competencies and responsibilities) that can adjust their processes and respond to market opportunities, or organisations with up-standard ICT capabilities. This process starts with the identification of customers' requirements. Each time an opportunity is identified within a scope of products and a market defined by a purpose of a web, its members are being activated in order to fulfil the identified need. A VO assigns satisfiers to customer requirements in three steps: (i) define abstract customer requirements, (ii) identify possible satisfiers, and (iii) assign concrete satisfiers to customer requirements. Such assignment criteria are specified in accordance with organisational goals. The effective performance of a VO involves high adaptability and flexibility, efficient input of resources, high product and service quality and the reduction of costs (Mowshowitz 1999).

On the third layer, a VO is goal-oriented cooperation between a subset of organisations that is focused on the realisation of a specific objective. During the formation of membership, tasks and responsibilities are assigned to each member as well as detailed coordinating mechanisms are formulated and allocated. ICT enables the coordination of activities between members. When a market opportunity has been exploited, the related operations of a VO are terminated. All knowledge and experience of working together is spread between members. Knowledge is used to update the assignment criteria and evaluations of potential organisations and to reflect ways in which members are expected to work together in the future (Saabeel et al. 2002).

This three-layer model is a theoretical construct. In reality, it may be difficult to hold on to these three layers (dimensions). For example, it is difficult to distinguish between a VO and a dynamic web in some cases. This is because some degree of formalisation already exists in a dynamic web when members have agreed on many important boundary issues. At the same time, a degree of goal specificity may vary from one VO to another. A VO that aims at fulfilling a specific customer order has a very specific goal, while an aim of fulfilling a more general market opportunity is less defined, (Saabeel et al. 2002).

3.4 CM

3.4.1 Generic CM services and methods

Management of construction addresses how available resources can be best applied. Resources are the five Ms, or manpower, machine, money, material and management. The focus of CM is on planning and control of resources within a framework of a construction project (Pilcher 1992). Projects develop in a sequential, linear fashion where the **eight general steps** include (i) identification of an owner's need for a facility, (ii) development of initial feasibility and cost projections, (iii) making of a decision to proceed with a conceptual design and a design professional is retained, (iv) the development of a conceptual design and a scope of work include an estimate of cost and a decision to proceed with the design work, (v) actual development of final design documents defines a project for construction purpose, (vi) the project is advertised and proposals to include quotations for construction works are sought, a contractor is selected based on retrieved proposals (tenders) and a notice to proceed with actual construction work is granted. A winning proposal and its acceptance by an owner constitute (vii) the formation of a contract of work so that construction process is initiated, work is completed and a facility is available for acceptance and occupancy, (vii) in complex projects, a period of testing is needed in order to determine if a facility operates as designed and planned, and (viii) at the end of a life cycle, a facility is disposed of or, if appropriate, it may be maintained for good (Barrie & Paulson Jr. 1992, Woodhead 1998).

Construction as a service activity has many dimensions. The business side is one of them. Business aspects require the establishment of **contractual relationships** with many parties of a project. Construction contracts structure a way in which construction is purchased. A facility is purchased based on a set of drawings and specifications before it is manufactured. A purchaser coordinates all designer(s), contractor(s), speciality contractors and vendors. Therefore, project delivery systems have been developed to provide construction buyers (clients) with a single point of contact or a source of purchasing (Barrie & Paulson Jr. 1992). Many contract formats have gained popularity over the past twenty years and they are still evolving. Two major varieties of contract formats have been designed to provide clients with construction equivalent of one-stop shopping; these are design-build contracts and CM contracts (Woodhead 1998).

In **design-build contracts**, it is beneficial from a client's point of view to have a single contractor provide an entire project as a single contract package. Large companies provide both design and construction services in order to provide a client with a single source for project delivery. This is

viewed as a natural evolution beyond negotiated contracts. Design-build contracts are common in industrial construction for complex projects with tight time requirements. Design and construction can be done concurrently so that work can be started on site before the design is completed. This allows phased construction (fast tracking) and schedule comparisons. In the building sector, design-build contracts are marketed as a way of receiving the best products in the timeliest ways and at the best prices. Since most building contractors do not have an in-house design capability, lead contractors form a team or a consortium of designers and speciality contractors who work together to meet the needs of a client. An owner/client contracts with a consortium as a single group providing a total project package (design, construction, procurement, etc.). Each member of the consortium is at risk and is motivated to work with other members to minimise delays and disputes (Walker 1996).

In **CM contracts**, the purpose of CM can be defined as a group of management activities related to a construction programme, carried out during the pre-design and construction phases that contribute to the control of time and cost in the construction of a new facility (Haltenhoff 1998). CM contracts are attractive to organisations that build complex structures (such as municipalities, hospital authorities, etc.) but do not wish to maintain a full-time construction staff to supervise projects on a recurring basis. An owner can obtain a company as a construction manager to plan, develop and coordinate the activities of one or more design professionals, trade contractors and vendors. A construction manager establishes procedures for the awarding of all contracts to an architect, engineers, principle vendors and trade contractors. Once contractual relationships have been established, a construction manager manages a prime or major contractor, subcontractors, major vendors and off-site fabricators. A CM company uses a project schedule as a tool to keep things moving forwards in a timely and cost-effective manner (Woodhead 1998).

CM consulting forms preceded CM contracting forms and still dominate in the public sector due to statutory requirements to publicly bid for construction work. In most public CM contracts, the conflicts of interest are prevented by regulating that construction managers are not allowed to take a CM contractor position after having been selected to perform preconstruction agency services. **CM contracting forms** predominate in private work. However, a construction manager is not precluded from the self-performing portions of the work that it customarily performs. A CM contractor acts as a general contractor. A client has only one contract with a

CM contractor. Besides, a client can have a building development consultant as a separate agent to improve a client's organisation and construction knowledge. A CM contractor holds trade contractors as subcontractor and is usually a general construction company or a specialised CM contractor. The primary advantages of CM are perceived as to provide a better service to owners by virtue of a dual agency relationship between designers and construction managers, and better overall coordination of projects due to early cooperation among three principal parties. Time compression of a design/construction process significantly reduces an overall project duration. Costs are also saved due to the early establishment of cooperative relations and time compression, particularly in periods of high inflation, as well as fewer disputes, claims and delays (Dorsey 1997).

The two types of CM can be briefly **compared** as follows. In **CM consulting forms**, an agency in any relationship is well defined, an agent acts in the best interests of a client and principle construction and design entities are agents to an owner and function at equal levels in providing services. A CM consultant functions well in both private and public sectors. A construction manager coordinates and monitors trade contractors who become direct (prime) contractors to an owner. An owner holds contracts, not a CM consultant. Nonetheless, an owner may assign contracts to a construction manager for a tighter administration. A CM consultant renders services to expedite a project, including recommendations regarding phasing, scheduling, procurement and the division of work into trade contracts. The CM also monitors costs, time, quality, and safety, but does not take responsibility for them. The central role of the CM consultant is to provide leadership and administration for the project, planning and design (in cooperation with the designers) all the way to construction completion and building start-up.

In turn, **CM contracting forms** begin with construction companies acting in consulting roles for preconstruction services. At some point prior to construction, however, this CM contractor assumes a risk of delivering a project with a set price as an option. Much of the actual work is performed by subcontractors under subcontracts to a CM contractor, who may or may not self-perform work. A CM contractor is responsible for construction means, methods and the delivery of the complete work (Haltenhoff 1998, Woodhead 1998).

3.4.2 Characteristics of Finnish CM

In the context of Finland, CM has been defined as "a form where a professional construction management organisation leads a project in close cooperation with a client. A construction manager decides the schedules of both design development packages and those of procurement packages and contracts. Construction works are carried out in several stages by multiple trade contractors. A client makes the final decision concerning design solutions, trade contracts and suppliers during an entire project" (Kiiras et al. 2002: 4). For a project, a client assigns its own staff and a CM consultant to a professional PM office that assists in effective decision-making. A PM office manages the development of design, procurement, contracting and often site operations. Alternatively, a client may prefer that a CM consultant (or a CM contractor) runs an entire PM office with its professionals. The relationship between a client and a construction manager is based on open cooperation where a construction manager acts as the right hand of the client. A construction manager prepares a project plan that consists of a detailed cost estimate, a procurement breakdown and plan, a target budget by procurement packages, a master schedule, project organisation, communication and decision plans as well as a risk analysis. A CM project is executed in two phases, i.e. (1) a target setting phase (the definition of a project) including programming (briefing), sketch (overall) design and detailed project planning, and (2) an execution phase involving the concurrent development of final designs, procurement and construction work, contract by contract (Kiiras et al. 2002: 1-15) (Figure 6).

3.4.3 CM forms in Finland

There are two CM forms in Finland, CM contracting and CM consulting. Clients can choose **(1) CM consulting** with or without site management. A client assigns its own staff to a PM team. A CM consultant acts as an agent of a client. Its core services include PM, procurement and the supervision of construction works. It relies on its expertise, management systems and specialised software. A client signs and holds all trade contracts. Site management is usually undertaken by a construction contractor. When a CM consultant is responsible for site management, this arrangement resembles a main contracting form. Site management entails wide responsibilities concerning site health and safety as a whole (Kiiras et al. 2002) (Figure 7).

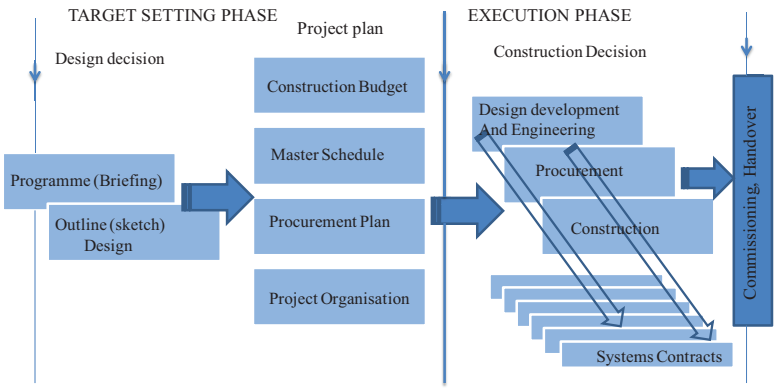

Figure 6. Two-phase model of a Finnish CM project (Kiiras et al. 2002: 5).

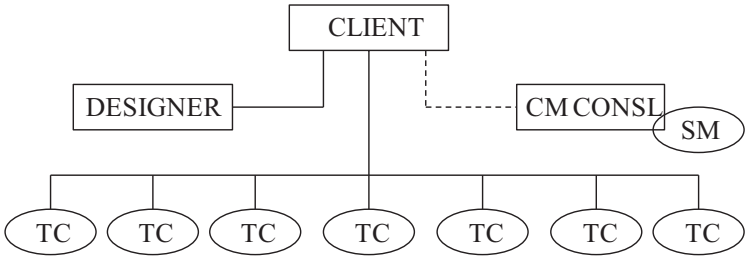

Figure 7. Contract relations in CM consulting with site management (PM services) in Finland (Kiiras et al. 2002: 9). (Key: CM CONSL = CM consultant, TC = Trade contractor, SM = Site manager).

When Finnish clients choose **(2) CM contracting**, a CM contractor is responsible for a project as a whole, including PM, construction work and site management, facilities and services. In addition, a client may rely on a separate building development agent (consultant). A CM contractor assigns its own professionals for managing a project and holds trade contractors as subcontractors. A CM contractor cannot use its own workforce or site facilities because everything is being procured (this is one main difference with cost-plus-fee main contracting). The role of a CM contractor is usually assumed by a general construction company or a specialised CM contractor. The client holds direct contracts with designers. The client is the ultimate decision-maker concerning design solutions, procurement and subcontracting in CM contracting. (Figure 8) (Oyegoke 2001, Kiiras et al. 2002).

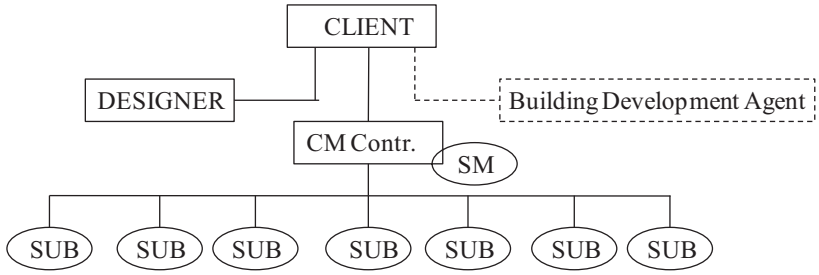

Figure 8. Contract relations in CM contracting in Finland (Kiiras et al. 2002: 10). (Key: SUB = Subcontractor, CM CONTR = CM contractor, SM = Site manager).

3.4.4 Other national CM forms: the USA and the UK

In the USA, CM is practiced in two general forms, i.e. agency CM and CM-at-risk. In all variations, a construction manager is responsible for preconstruction services and the general administration of works such as scheduling meetings, making payments and guarding safety. In **agency CM (or CM-for-fee) contracting**, a construction manager assumes the role of a consultant in preconstruction and construction phases as well as administers, co-ordinates and monitors work contractors. An owner holds all contracts with designers and contractors as well as bears risks on cost, time and workmanship. A CM consultant's risk is on his professional liabilities and negligence. In **CM-at-risk contracting**, a construction manager acts as a consultant in a preconstruction phase and as an equivalent of a general contractor during a construction phase. A construction manager holds all subcontracts and bears risks on time, cost and workmanship quality. A construction manager provides preconstruction services as an agent, holds subcontracts and provides a guaranteed maximum price (GMP) and a fixed contract period. A construction manager assumes financial responsibility for construction works and may or may not perform some works with own resources (Dorsey 1997, Oyegoke 2007).

In the UK, there are two basic CM contracting systems, i.e. construction management contracts and management contracts. In **construction management contracting (CMC)**, an owner assumes a contractual position of a main contractor and engages directly works contractors to carry out construction works as subcontractors. In turn, a construction manager acts as an owner's agent being responsible only for works related to the setting up of a site and works associated with preliminaries. **In**

management contracting (MC), an owner appoints first a professional team that prepares project drawings, specifications and bills of quantities which broadly define a project scope. An architect is usually the head of a team. An owner also appoints a management contractor at an early date to act as a project planner, manager and organiser. A management contractor provides site supervisory, technical and administrative staff as well as puts in place special facilities to be shared by subcontractors. A management contractor plans, co-ordinates, organises, supervises and generally manages and secures construction works (Oyegoke 2007).

In Finland, the USA and the UK, CM consulting includes the national forms of CM consulting, agency CM, and CMC, respectively. In turn, CM contracting includes the national forms of CM contracting, CM-at-risk, and MC, respectively (Oyegoke 2007) (Figure 9).

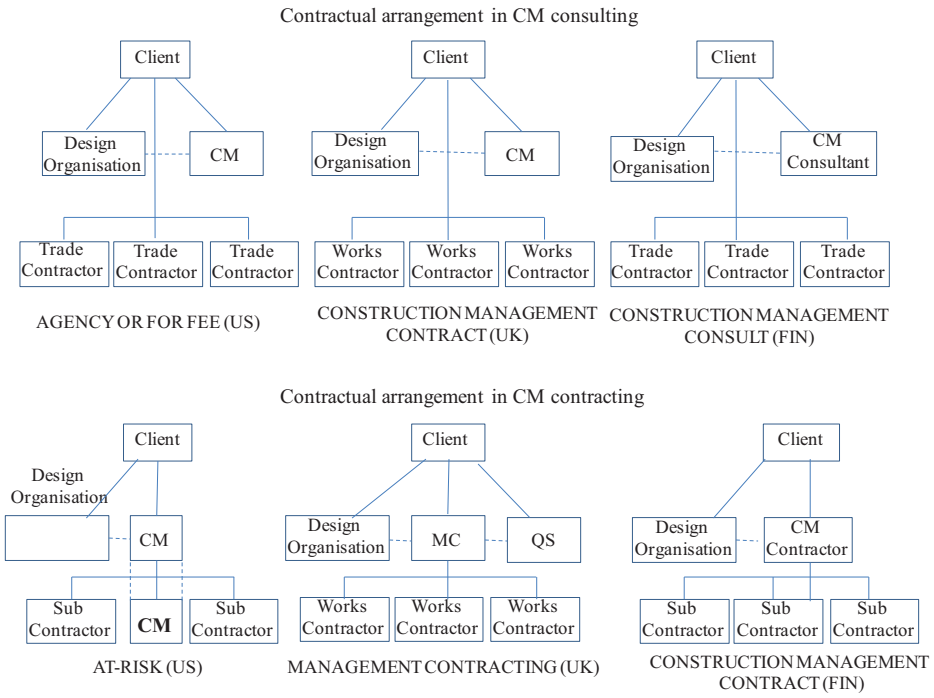

Figure 9. Comparison of CM consulting and CM contracting perspectives in the USA, the UK and Finland (Oyegoke 2007: 24)

3.4.5 Specialty systems contracting in Finland

By the end of the 2000s, all such forms of **partnering** that were based on long-term and one-to-one relationships had so far resulted in a loss of real

competitiveness in building markets in Finland. In turn, the penetration of CM contracting forms has been coupled with the emergence of **speciality system contracting,** where design responsibilities are in part transferred to speciality system contractors (SSCs) that couple them with their product design and production planning (Salmikivi 2005). When competition is based on design solutions, material choices and production efficiency, speciality system contracting forms do not discriminate between construction techniques and materials so that competition expands from production know-how to system know-how and from details to total solutions. Indeed, when competing with solutions, it is possible for SSCs to come up with more innovations and develop their production (Salmikivi 2005). So far, **many Finnish subcontractors and building product suppliers** have taken responsibility for system design, detailed engineering, manufacturing and installation of building systems or elements including the in-use-performance of a system as defined by a client (an owner).

In comparison, SSCs are responsible for a wider scope of work in Finland than traditional speciality contractors do in the United States (Tommelein & Ballard 1997). The former are also responsible for designing and engineering their systems while the latter are mainly interested in the design phase of products.

3.5 Enabling IT and virtualisation in construction

3.5.1 ICT

It has been argued that the importance of the **ICT revolution** is of a similar scale to that of the industrial revolution. ICT is seen as a backbone of major structural transformations. ICT offers a basic infrastructure for the information society and the completely different and functionally interrelated world economic system (Sun & Howard 2004). Changes require adaptations within companies and fundamental revision of corporate strategies. In turn, the flexibility of VOs is based on computer-mediated communication systems such as an electronic mail, network conferencing facilities and PC video links. In practice, remote individuals are becoming engaged in computer-supported collaborative work. Teleworking allows the workforce to become highly dispersed and permits work to be released from the traditional location constraints of a single, common workplace and the time constraints of the current working day.

Many new forms of flexibility require changes in relationships and control between organisations and human resources. Command-and-obey management is being replaced with mutual synergies (Barnatt 1996).

Global computer networks appear to be an ideal infrastructure for the development of virtual companies. This brings up the question **"How do companies use a global computer network, such as the Internet?"** The answer is herein accomplished by addressing the three related issues as follows: (i) The **characteristics** of a global computer network involve companies that are setting up basic, flexible communication structures through which users can draw capabilities as they are needed. The Internet has become so attractive as a consequence of the rapidly increasing number of users, the recipients of marketing and product information as well as the other positive agglomeration effects. When a volume of transactions is growing manifoldly and the main costs of the infrastructure (hardware and a physical network) are fixed, costs per unit transferred are significantly decreasing (Maier & Traxler 1995).

(ii) In the **global economy**, companies coordinate their activities in all parts of the world and observe trends, changes and activities in competition. Globalisation and integration increase competition. New products are marketed immediately and globally. The shorter life spans of new products are coupled with highly efficient production. Rapid technological developments and frequent changes in demand require high flexibility in internal organisations. Locations for the parts of production processes are optimised. Risks and/or costs are minimised through cooperation. Thus, formal and informal networks on many spatial levels are being developed and exploited between collaborative companies (Maier & Traxler 1995).

(iii) The **information society** is dependent on information and organised around knowledge for the purpose of controlling social relations as well as directing innovations and changes. Social structures are organised around the interests of information holders. The automation of the most standard production and management functions with interlinkages are controlled through information and knowledge. When vast amounts of knowledge are produced and distributed, the roles of the workforce are renewed accordingly (Maier & Traxler 1995).

3.5.2 Needs for IS and IT strategies in construction-related companies

In the late 1990s, Betts (1999) already foresaw that the construction industry was facing new, rapidly changing environments where increasingly sophisticated clients expect companies to deliver high-quality outputs and to achieve radically improved performance. Construction-related companies had to become forward-looking. The adoption and use of **IT solutions** were adopted as an integral part of strategic planning in large companies. A move began towards strategic IT planning. Construction-related companies initiated IT-enabled strategies in order to develop future businesses. Thus, all IT development was business-driven. IT should play a role in and be integrated with the business processes of the construction industry (Betts 1999) (Figure 10).

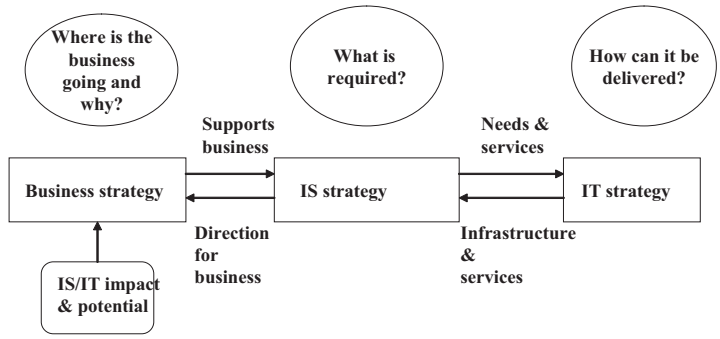

Figure 10. Business strategy, IS strategy, IT strategy and their relationships (Betts 1999: 146).

In construction-related companies, **information system (IS) strategies** today (i) bring together the business aims of respective companies, (2) provide an understanding of information needed to support those aims, and (3) facilitate the implementation of information systems for dealing with that information. IT strategies are procured and implemented through (i) choosing systems, selecting software and solutions as well as rolling out and supporting systems, (ii) implementing process changes, setting up project teams, seeking an integration, sequencing projects, defining timescales and resources as well as searching for relevant applications, (iii) specifying systems, choosing between bespoke systems and packages as well as selecting the suppliers of software development processes and (iv) auditing skills, preparing data, training and consulting users as well as establishing help desks for user groups (Sarshar et al. 1999, Sun & Howard 2004, Kazi 2005, Kazi & Wolf 2006).

4. DESIGN OF A THREE-DIMENSIONAL VIRTUALITY MODEL AND A MAXIMUM VIRTUAL CM FIRM MODEL

The study including this model design task was triggered by prior developments in the building markets in Finland. In the early 1990s, Finland experienced a deep recession that had its negative consequences on the construction industry as well. New, CM-based competitive pressures pushed the top management of traditional, integrated construction contractors to change their strategies and principles of organising by streamlining their organisations. By the mid-2000s, the strongest CM contracting firms had already secured their positions, particularly in new complex buildings sector, as well as having diversified their CM services into other complex areas in infrastructure and renovation markets. In turn, this long-term study process was started with the ideation of some possible forms for the virtualisation of both building contractors and CM firms (Kiiras & Huovinen 2004, Alsakini et al. 2005).

In this chapter, a model of virtuality is designed along the three selected dimensions, i.e. collaborative management, outsourcing and competitive networking. Based on this first model, a model of a max VCMF is designed in terms of a novel definition, an IIS as well as an integrated network and PM system and its seven subsystems as follows.

4.1 Three-dimensional model for virtualisation of CM firms

A **three-dimensional model** is herein designed as a virtual space that explains how CM firms manage their virtuality and operate along one, two or all of the three dimensions of collaborative management, outsourcing of operations and competitive networking (Figure 11). At the outset, the relationship between this three-dimensional model and the max VCMF

model is determined so that a VCMF is seen as an **operation mode** along the three-dimensional virtuality.

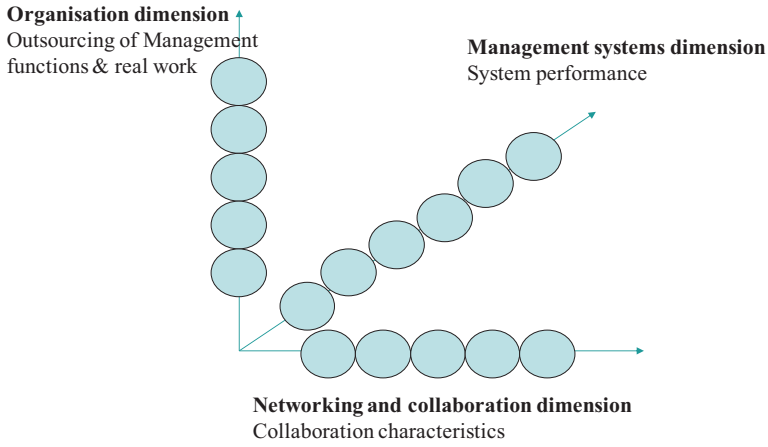

Figure 11. Three-dimensional model of the virtualisation of CM firms.

4.1.1 Collaborative management system (first dimension)

Along the management dimension, a virtualising CM firm manages conventional project work and relationships with clients and among SSCs, designers and suppliers. Indeed, traditional construction PM systems are herein considered incomplete. Instead, an **effective IT-enabled collaborative management system** is designed to consist of seven subsystems as follows (Alsakini et al. 2008b):

(i) A project owner relationship management system enables enhancing the quality of services through a pre-emptive expert relation development with targeted existing clients and potential new ones.
(ii) A project offering and bidding management system enables the virtualisation of related processes in order to generate the most attractive solution to each client.
(iii) A project design and engineering management system involves a building product model that allows each of the networked SSCs to exploit project and design documents on a real-time basis and to contribute early enough to the detailed design of packaged systems.
(iv) A networked project procurement management system enables competition within project network members that results in high

competitiveness in terms of procuring and integrating the best systems for a focal building, project by project.

(v) A construction planning, execution, and control management system enables virtual construction PM based on an advanced process model in which workplace and master schedule plans are combined, as well as detailed activity plans and rolling window time schedules are exploited.

(vi) A commissioning and after-sales services management system enables a virtual life cycle management of a focal building in terms of facility management (FM), renovation, and other expert services.

(vii) A network nurturing management system enables a lead member to renew a competitive network on a continuous, proactive basis in terms of ensuring and developing core competencies for the design of innovative building solutions.

It is assumed that the extent and speed of virtualising traditional management systems vary significantly among firms. In each case, a focal firm makes decisions based on its **communications and IT strategy**, the availability of ICT-based systems vis-à-vis a need to pioneer these systems itself, software integration for ensuring data compatibility, Internet-based solutions and new critical training needs. Nevertheless, the seven subsystems are the key enablers for high performance. At any point in time, a **current degree of virtuality** can be measured along this management dimension by the collaborative and integrated IT-enabled systems and their combined share of a focal firm's total management system.

4.1.2 Outsourcing of operations (second dimension)

Along the outsourcing dimension, a virtualising CM firm can continuously transform itself towards a **flat organisation** by removing middle level management and maintaining only top and project management levels (Figure 12). A major lever towards becoming a VCMF is the outsourcing of functional units and tasks. Traditional staff members are encouraged to establish their own practices as entrepreneurs. Only existential functions, i.e. ownership, strategic management, bidding and communications management are sustained within the core. At the extreme, this means a radical reorganisation that management foresees necessary in order to survive in dynamic building construction markets (Alsakini et al. 2005).

It is assumed that the extent and speed of virtualising a traditional organisation along the outsourcing dimension vary markedly among firms. Typically, a focal firm decisions based on its perceptions on the existence or emergence of compensatory external markets and the level of its competencies to create and nurture a competitive network. In particular, it is vital to maintain one seamless face towards customers. At any point in time, a **current degree of virtuality** can be measured along this dimension as a volume of outsourced functions, e.g. by their combined share of a focal firm's total functions.

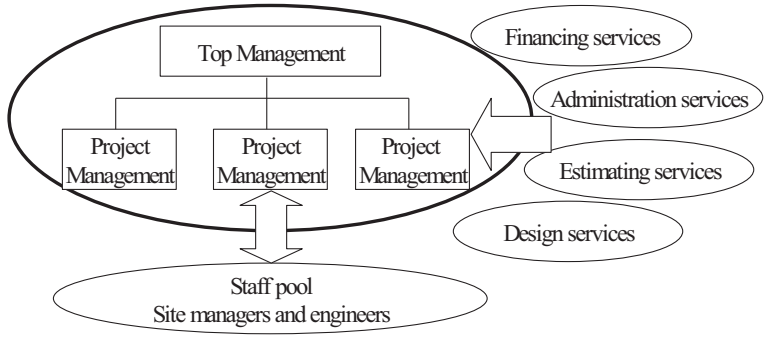

Figure 12. Flat structure of a virtualising CM firm.

4.1.3 Competitive networking (third dimension)

Along the networking dimension, a virtualising CM firm manages a portfolio form of collaboration in order to achieve a targeted degree of virtual competitive networking. Collaboration is enhanced primarily **between a core and a competitive network of SSCs** (Alsakini et al. 2008) (Figure 13). SSCs provide clients with a complete building based on their modularised systems in terms of design, engineering, procurement, manufacturing, delivery, installation and after-sales services. System types include various building systems (e.g. structural building frames), modules (e.g. rooms), building products (e.g. windows) and functional elements (e.g. indoor climate). Trust between a focal firm and SSCs replaces the traditional mechanisms of coordination and control. In principle, a focal firm may network with competent SSCs on a one-to-one, one-to-few or one-to-many basis. However, profitable performance is endangered without

internal competition. Typically, a focal firm maintains an internal competition between two or more SSCs that supply the same systems, modules, functional elements or other services (Alsakini et al. 2006b).

In addition, a focal firm continues to exploit other external suppliers of various building products, construction materials and life cycle services.

It is assumed that the extent and speed of creating a competitive virtual network will vary markedly among firms. Typically, a focal firm makes its decisions based on the availability of new competent SSCs, the foreseen higher degrees of trust-based relations, and the effective use of ICT applications needed to allow a virtualisation process to proceed faster. At any point in time, a **current degree of virtuality** can be measured along this dimension by the competitive and collaborative characteristics and their role within a focal firm.

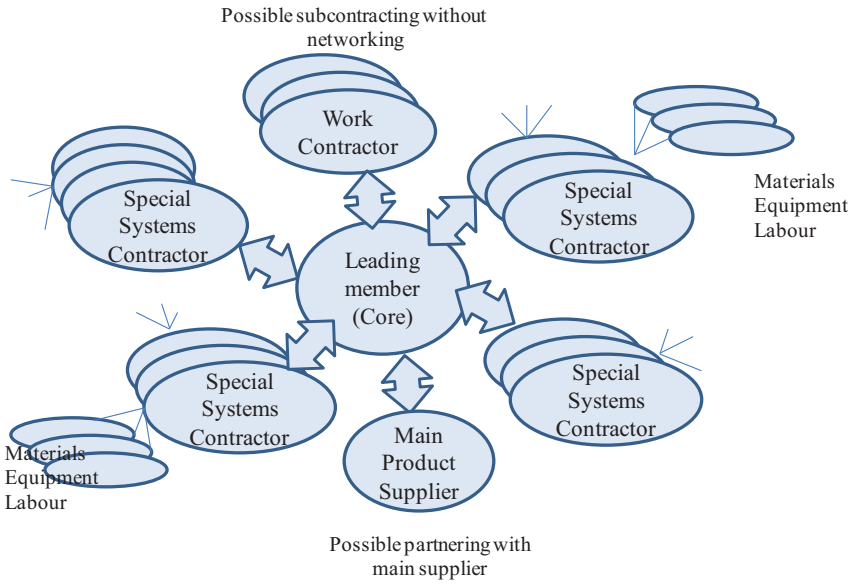

Figure 13. Competitive network of SSCs and other project stakeholders around the core of a virtualising CM firm (Alsakini et al 2008).

4.2 Maximum VCMF model

A theoretical model of the **max VCMF** is herein designed as follows. The max VCMF is a highly operational mode and it exhibits the highest characteristics within the three-dimensional virtuality. The attributes of the max VCMF can be used as a reference for managing the virtualisation of

CM firms in the absence of a real-life, fully virtual CM firm. In addition, the max VCMF model can be used to benchmark other construction companies for measuring their degrees of virtuality, respectively.

4.2.1 Definition of the max VCMF

A definition of the max VCMF consists of **six sub-definitions** (areas) as follows.

(1) The max **VCMF** is a **dynamic network** of collaborating, legally independent firms that reconfigure around a core or a single lead member whenever a CM services business opportunity arises in relevant building markets. A lead member guides a virtual network on a short and long-term basis. Members are geographically dispersed firms, organisational units and teams. Each member concentrates on those parts of the value chains with which it achieves an added maximum value. At the same time, the max VCMF is a **purposeful system** that is composed of interrelated actors (organisations and individuals), resources (core competencies) and activities. Relationships between actors are structured by a purpose, connectivity, boundaries and ICT (applying Balint et al. 1998, Fleisch & Österle 2000, Bauer & Köszegi 2003).

(2) The **essence of being** the max VCMF is embodied in its flexibility to adapt itself to rapidly changing businesses and to bridge gaps between required and provided competencies, different times and separate locations where services are requested (applying Goranson 1999). This maximum entity is capable of dealing with complexity and uncertainty through cooperation among networked members. It has an ability to alter a value creation process by applying switching. It delivers highest customer values through the constant allocation and dynamic assignment of process parts to satisfiers (applying Mowshowitz 1999, Franke 2001; see also p. 2).

(3) In the area of **structural organising**, the max VCMF is flat. A lead member manages and nurtures a competitive network of SSCs, designers and a staff pool. The management system consists of a network and project management model that is integrated by a building construction information model (BCIM). The network and project management system is IT-based and supported by an IIS (Alsakini et al. 2006a). The key organisational and structural characteristics are as follows:

- Middle level management is removed.
- Functional units such as cost estimation, procurement and building design services are outsourced.
- Prior internal project staff members are encouraged to act as entrepreneurs and form a staff pool from which a lead member assigns key staff to each project.
- Client accounts enhance the true engagement of account managers in quality assurance and client care.
- Financing and administration are outsourced, i.e. they are bought as services from reliable, specialised firms.
- No bureaucratic structures and administrative overheads remain.
- A remaining flat structure consists of firm management and experienced project managers.

(4) In the area of **life cycling**, the max VCMF may go through all four phases of identification (seeking members), formation (contracting), operation and termination. In other words, a particular entity may be terminated by a joint decision or a decision made by a lead member alone. Each phase contains specific tasks, decision processes and management activities (applying Franke 2001, Saabeel et al. 2002, Bauer & Köszegi 2003). At the minimum, a change process involves designing a new network, restructuring and outsourcing operations, and strategising of new business creation (Kiiras & Huovinen 2004).

(5) In the area of **managing business processes and projects**, the max VCMF is capable of renewing itself by designing and implementing new business processes. The **seven core business processes** include (i) project owner relationship care, (ii) project offering and bidding, (iii) project design and engineering, (iv) networked project procurement, (v) construction planning, execution and control, (vi) commissioning and after-sales services, and (vii) network nurturing. For each project, one project manager is assigned to carry out PM responsibilities. For the design phase, a project manager heads a building design team together with client representatives, an architect, various engineers and a consultant. During a bid or proposal preparation, a project manager heads the buying of estimation services and the allocation of procurement packages via competitive networking (applying Alarcon 1997, Baden-Fuller et al. 2000). When a particular bid is won, a project manager mobilises a site organisation from a staff pool and manages the construction phase. Firm management is responsible for arranging and developing a competitive and collaborative network with selected members as well as enhancing supplier

relationships and assuring each member's additional competencies in the case of possible extensions of a contract scope. Each project manager retains the responsibility to hand out procurement contracts for her/his ongoing project.

(6) In the area of **competitive networking**, the delivery system of the max VCMF consists of a dynamic network of SSCs, designers and a staff pool. A virtualised strategy supports the extension of delivery and contract scopes, a decrease in the number of individual deliveries and the creation of network memberships with the most important SSCs (and subcontractors and suppliers). In particular, collaborative SSCs are seen as legally independent core competencies that are combined within the VCMF to produce an optimised value chain under each CM contract, i.e. to ensure building (product) flexibility, design changes flexibility, short delivery times and the concurrency of design, procurement and construction works on site (Kiiras & Huovinen, 2004, Salmikivi 2005). Special system contracting is limited to encompass only large systems where SSCs are assuming responsibilities to self-manage planning, scheduling and the control of their own activities. Competitive networking implies that a lead member networks with several special product contractors that supply the same products, functional elements, or services.

A competitive, SSC-based network is created and integrated via its **structural characteristics** (mechanisms), i.e. modularity, heterogeneity, connectivity (loose coupling), sourcing, contracting, duration and spatial distribution. More planning and control activity is given to each SSC over its own system delivery and finger pointing is reduced in the event of interfacing contractors with different priorities (Domberger 1998, Gadde & Håkansson 2002). Similarly, **soft characteristics** (mechanisms) involve a purpose, boundaries, a degree of involvement, trust and fairness that serve as the glue in sustained collaboration (applying Camarinha-Matos et al. 2005). Networked SSCs are motivated to add value-for-client money through their system knowledge and modularised expertise, whereas a lead member focuses on enhancing CM expertise, virtual processes and its staff pool.

It is herein argued that none of existing CM firms around the globe in the building industry complies with all the characteristics of the max VCMF. However, there may be many CM firms that readily exhibit several characteristics of virtuality in various national and international contexts. Value creation and capturing are seen as a necessity, driving traditional

firms to restructure themselves. Over time, pioneering CM firms (and building construction) will set their long and short-term goals of virtuality and couple them with the **targeted degrees of planned virtuality**. Later, the targeted versus actual degrees of virtuality can be measured over time against the characteristics of the max VCMF.

4.2.2 ICT strategy and IIS of the max VCMF

The **ICT strategy** of the max VCMF determines the scope, performance levels and specific requirements for modern ICT-based solutions and systems that support all operational processes, inter-organisational and intra-organisational communications, information flows as well as internal and external relationships. This strategy guides the selection and buying of well-known commercial software/applications that match the requirements (Alsakini et al. 2006, 2008c).

The IS/IT strategy is realised via the **IIS** of the max VCMF. This IIS enables users (i) to access and update information efficiently based on access rights, (ii) to synthesise different pieces of information and organise existing knowledge, (iii) to view well-organised information from various perspectives depending on their role in a process, (iv) to accumulate knowledge in an orderly fashion for future usage, and (v) to generate reports for decision-making (applying Chan and Leung 2004, Kazi et al. 2001, Kazi & Hannus 2002). The effective purchasing of software/applications solves the flexibility problem. The distribution of software/applications and training of members to use the same applications solves the integration problem. An IIS exploits **three information nets,** i.e. (i) the Internet, using standards such as web servers and browsers so that members communicate as well as find, use and share documents behind a firewall, (ii) an extranet allows for controlled access from the outside by trusted clients and networked members to the max VCMF's database for specific business purposes via the web, and (iii) an intranet, ICT-based solutions and customised area-specific IT systems facilitate the exchange of information and communications within the max VCMF network (applying Kazi et al. 2001).

The max VCMF relies on **several mechanisms** to enable the effective sharing and exchange of information among its members in a competitive network as follows: (1) A point-to-point information (file) exchange, where providers and recipients have similar software/applications to enable them

to work on the same information (2) Project servers, i.e. information are stored in a central repository that is accessed by those who provide and seek relevant information. Servers resolve data/information redundancy problems and maintain information centralisation. (3) Links between enterprise systems, i.e. an individual communicates with a central repository of a firm for which (s)he is working and this repository releases a relevant portion of this information to a shared project-specific repository. Firm-specific systems/ repositories transfer and receive information packages, both product information and management/process information, on a periodic basis or based on requests to/from a specific project server (applying OSMOS 2000, Kazi & Hannus 2002).

4.2.3 Integrated management system of the max VCMF

The **integrated network and project management system** of the max VCMF consists of two integrated models, i.e. a seven-subsystem management model and a three-part building construction information model (BCIM) (Firat et al. 2009). The integration is realised by an IIS (Figure 14) (Alsakini et al. 2008c). In turn, each of the three sub-models of the BCIM (Figure 15) support certain phases of a project by using information stored in generic libraries (Firat et al. 2008a, 2008b, 2008c) as follows:

(1) A **building product model (BPM)** targets a finished building as a set of interdependent design objects, i.e. spaces (space model), building elements and product structures or receipts (building products or construction materials), at the minimum. Each building-specific data model is scalable. More and more detailed documents are uploaded into the model during the consecutive stages of a building design process. Visualisation is enabled with information about spaces, infill, surfaces, textures and materials. Generic building element structures (BES) are stored, updated and reused via a library. A building product model is being updated based on design changes incorporated in a building D&E management system.

(2) A **building project resource and cost model (BPRCM)** targets a building project as a set of interdependent resource objects, i.e. the amounts of building products (retrieved from a building product model) and resource structures or receipts, with current prices, planned for exploitation through the construction and installation of these building products. In particular, this resources and cost models involve the system-

specific sub-models that are interchangeable among internally competing SSCs. Generic building project activities with their resource structures and prices (RSP) are stored, updated, and reused via a library.

(3) **A building construction process model (BCPM)** targets a building project as a set of interdependent activity objects, i.e. the frequencies of project activities or tasks that are coupled with their resource structures (retrieved from a resource and cost model) and durations calculated by resources. In particular, this process model involves system-specific sub-process models that are interchangeable among internally competing SSCs. Generic building project activities, their planning rules and interdependencies (APP) are stored, updated and reused via a library.

Each member or user has their own partial models and releases a subset (partial model) of them as part of a central repository. These subsets are combined according to current and changing requirements and each new composite model is re-shared. This procedure ensures that a consistent model can be seen and used in its entirety or as those parts that interest a particular member.

In addition, the **internal dynamics** of the max VCMF is elaborated upon based on the interaction between the seven subsystems of the network and project management system and the three parts of BCIM (as illustrated in Figures 14 and 15) as follows. Designers and SSCs work with the compatible software/applications provided by a lead member, i.e. a project team relies on an object-oriented product model system from the outset so that they can exchange their working files with a design team.

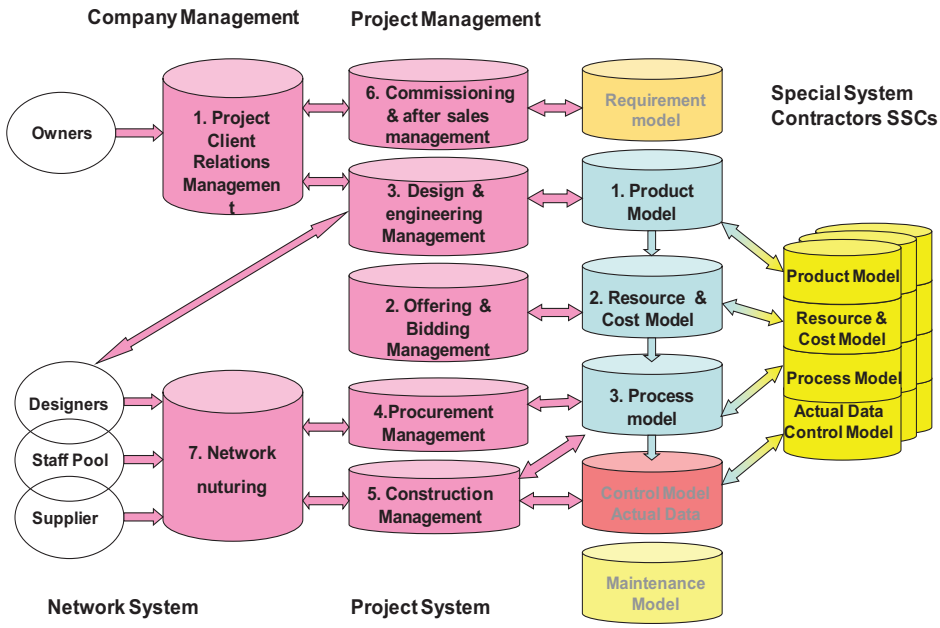

Figure 14. Seven project and network management subsystems and interfaces of the max VCMF integrated via a three-part BCIM.

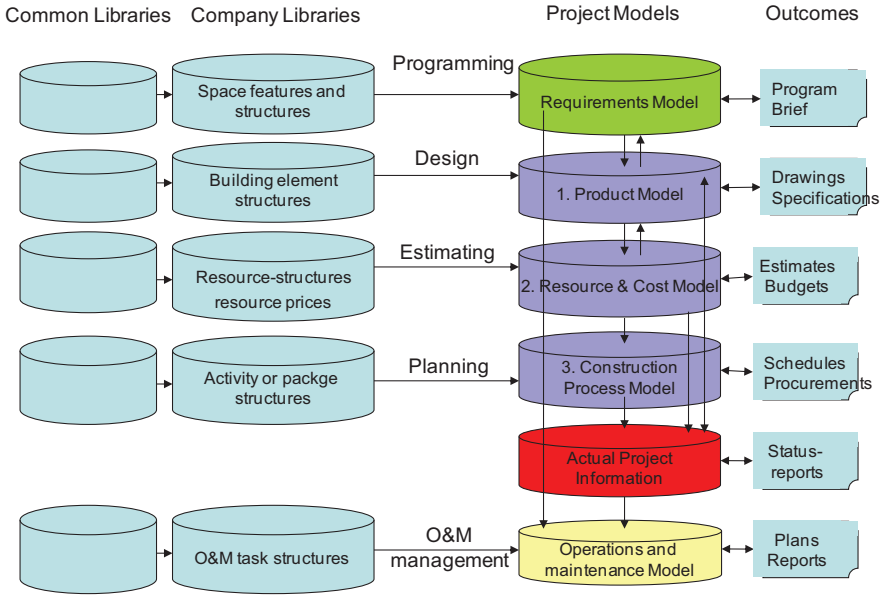

Figure 15. Three-part BCIM of the max VCMF (Firat et al. 2009)

A product model is installed on the max VCMF's server early in each project. This server is accessible to all actors of a project. All revised and more detailed designs by designers and SSCs are added as layers to the original design. The validation of the design including checks for consistency and clashes is achieved at the same time, resulting in a consistent product model. A product model becomes the basis for producing a resource and cost model by providing the information needed for deciding upon a work breakdown structure (WBS), preparing a list of bid packages to be tendered by SSCs and procuring bills of quantities and cost estimates from expert consultants. In turn, this resource and cost model becomes a basis for producing a process model to provide information for the procurement, construction tasks and site activities with their interdependencies, durations and costs. Compatible software for CM activities enables SSCs to incorporate their detailed activity plans, where each activity is presented in a rolling window, into a real-time master plan of a lead member during construction for control purposes.

4.2.4 Seven subsystems of the integrated management system

The subsystems of the integrated management system of the max VCMF are **specified in more detail** as follows. The first (serving CRM) and the seventh subsystem (nurturing of a network) are new subsystems in the focal context. Instead, the other five subsystems can be realised with proven, well-known IS software and solutions.

(1) Project Owner Relation Management System (PORMS)

Within the max VCMF, the role of a project manager is vital for mutual trusting relationships and client satisfaction. Project managers' tasks include meeting clients' expectations in terms of focal building needs (investments), past and direct experiences with this same VCMF, transparent exchange of word-of-mouth information, marketing activities and image issues (applying Smyth 2000). The max VCMF enhances the quality of its services through **pre-emptive expert relationship building** with targeted existing and potential new clients (owners). In particular, the abundance of various contacts through a pool of networked members enables a VCMF to generate repeat business, positive rumours, and so on. Through **its project owner relationship management system (PORMS)**, a VCMF generates and updates lists of potential, targeted, existing and new clients. In turn, a special IIS facilitates a

PORMS' performance by providing real-time information for generating and updating such lists, contacts and registers based on a spreadsheet program (Figure 16). A typology of generic building types (via a product model) supports CRM in terms of designing, visualising and demonstrating emerging building needs as well as ensuring higher value-for-client money.

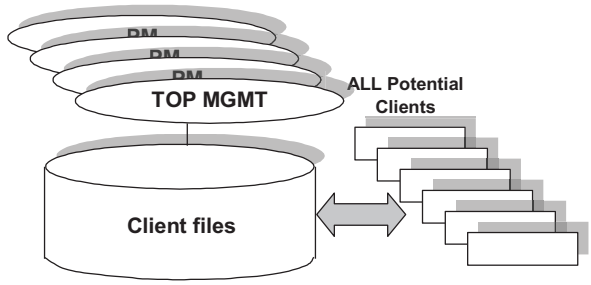

Figure 16. Project Owner Relation Management System of the max VCMF.

(2) Project Offering and Bidding Management System (POBMS)

Within the max VCMF, targeted buildings are broken down in order to define work scopes accurately as well as eliminate overlaps and gaps between work scopes as part of building bidding processes (applying Woodhead 1998). The max VCMF exploits multi-bidding and multi-contracting, thus minimising frequent and difficult trade interfaces, provides each SSC with as much construction continuity as possible and schedules effectiveness. Deciding on which work scopes to set aside depends on the match-up of SSCs and the requirements of the work scope (applying Haltenhoff 1998). A **lead member** collaborates with networked SSCs, designers and suppliers in order to generate the most attractive solutions for clients. The max VCMF primarily targets complex projects with large scopes so that the competitive advantages of SSCs can be fully exploited.

The max VCMF divides a building according to the principles of open building into systems of a **permanent base building** (a support or a shell and a core) and **flexible space infills**. The design and realisation of space infills are accomplished in accordance with users' space requirements. Concerning the independence of design and production, systems are divided into base building systems, permanent space systems, technical base building services systems, flexible space systems and site area systems. Base building systems contain groundwork, foundations, building frame,

roof, facades, permanent spaces, stairs, entrance halls, auditoriums, etc. Technical base systems include central equipment and fixed pipes, ducts and cables to the border of interior areas (technical core). Space infills are carried out by departments that are designed and procured as separate speciality system contracts. Therefore, space infills contain construction works and the design of technical systems. Production techniques are integrated with space parts (Salmikivi 2005).

The top management of a lead member makes all the decisions during networked bidding processes. In turn, a **project offering and bidding management system (POBMS)** enables related processes and assists bidders to understand client needs quickly, compile best offering, divide work scopes among SSCs and obtain the most competitive prices for each package. As a rule, each package is bid by at least three members (including external SSCs) that have room in terms of workload, available staff, resources and an interest in submitting a proposal (Figure 17). A focal building is pre-modelled by a client's design team or modelled under the guidance of the max VCMF, based on its product model. In turn, a special IIS provides a lead member with the information required for deciding upon a work breakdown structure (WBS) and preparing a list of bid packages. Based on the WBS, a lead member (i) procures bills of quantities and cost estimates from expert consultant(s) from the market, (ii) prepares a resource and cost model for the building in question, and (iii) distributes bid packages to networked SSCs for their bid preparation via the Internet. A competitive internal tendering process exploits the system-specific know-how of each SSC that submits its detailed sub-bid for a focal system package.

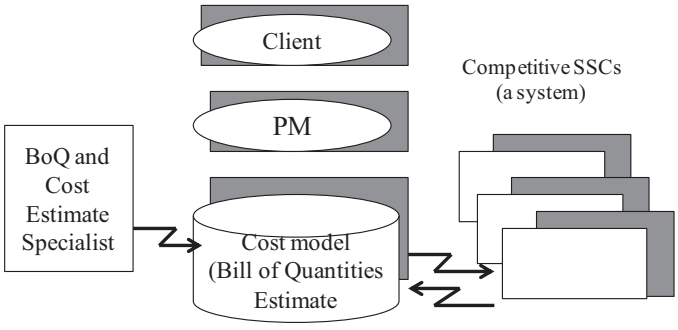

Figure 17. Project Offering and Bidding Management System of the max VCMF.

(3) Project Design and Engineering Management System (PDEMS)

Within the max VCMF, a **project design and engineering management system (PDEMS)** enhances constructability by providing SSCs with a platform to contribute early enough to the detailed design of project packages that are allocated to each SSC. A PDEMS enables a lead member to establish a product model as a core of a PDEMS that allows real-time access to the most recent design documents (Figure 18).

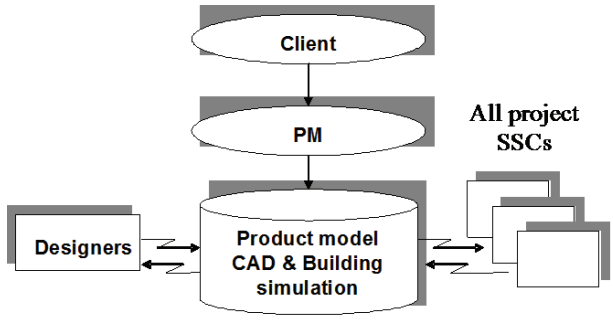

Figure 18. Project Design and Engineering Management System of the max VCMF.

A building-specific product model is provided by a collaborative design firm. Each SSC designs its system virtually. Each SSC reviews design layouts and identifies any conflicts between design, engineering and construction. A product model is an updated-in-real-time model, which means that design changes are incorporated into the product model. In turn, a special IIS links engineering analyses and design solutions so that the design process results in a complete product model that combines architectural and engineering simulation models to speed up the calculation and building simulation processes, as well as predicting the performance of each system and a whole building over their life cycles. Detailed engineering is performed by SSCs that use their know-how and expertise.

(4) Networked Project Procurement Management System (NPPMS)

Within the max VCMF, a **networked project procurement management system (NPPMS)** provides the members of a network with an internal arena in which to compete in order to come up with integrated best offerings. On the other hand, a lead member is able to move towards outsourcing those processes that are not part of its own core skills.

When a CM building project opportunity arises, a lead member notifies SSCs and sends invitations via Internet-based data transfer. In turn, SSCs prepare and post their offers/bids. A lead member selects bids and notifies the winning bidders, who in turn take part in detailed design, or do it altogether, and provide tailored solutions as part of their bid packages. A NPPMS enables real competitiveness in terms of integrating sub-offerings and procuring a set of speciality systems (of buildings), project by project (Figure 19). In turn, a special IIS includes a list of systems, processes, and services to be procured. During each bidding process, a lead member uses an internal list to select those SSCs whose work histories and profiles match speciality systems, expert processes and services needed in projects at hand and sends bid packages via the Internet to the selected SSCs for their sub-bid preparations.

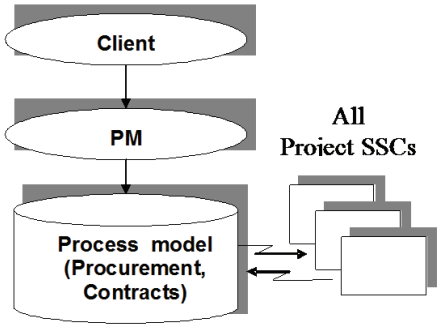

Figure 19. Networked Project Procurement Management System of the max VCMF.

(5) Construction Planning, Execution and Control Management System (CPECMS)

Within the max VCMF, a **construction planning, execution and control management system (CECMS)** provides a lead member or a construction PM team with an advanced planning system in which workplaces and a coarse general planning are combined, a detailed activity planning is made just before the beginning of each activity and short time rolling window is used throughout a project. Corrections are performed immediately. If work stops in one workplace, it is jumped over and a new team will be allocated (Alsakini et al. 2004a). A CECMSC enables a virtual construction PM with an advanced core, i.e. a master plan and a set of activity plans/schedules with rolling windows (Figure 20). A CPECMS system consists of (i) a planning and scheduling system and (ii) a cost

control system. In turn, a special IIS is designed to provide information for procurement, construction tasks and site activities with their interdependencies, durations and costs.

A master plan is produced in terms of systems or packages to be performed by SSCs. For control purposes, each SSC prepares its detailed activity plan/schedule and integrates this into a real-time master schedule. Design changes are fed into a process model so that up-to-date execution plans and schedules are available on an ongoing basis. Cost information is fed into a process model based on actual expenditure among SSCs and other subcontractors on site.

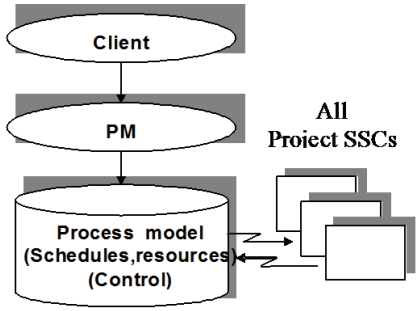

Figure 20. Construction, Execution and Control Management System of the max VCMF.

(6) Commissioning and After-Sales Services Management System (CASSMS)

Within the max VCMF, a **commissioning and after-sales services management system (CASSMS)** enables the virtual life cycle management of a focal building, i.e. clients gain better value and profitability for their investments in buildings through a life cycle management system based on the procurement of FM, renovation, expert and other services (Figure 21). The max VCMF does not provide itself such life cycle services; rather it assists its clients in finding the right expertise, in each case. In turn, a special IIS uses information being generated through six other management and information systems collectively, such as the profile directories of SSCs to find a match between a required performance and a commissioning plus after-sales services planned over the life cycle of a focal building. The max VCMF hands over an updated product model to

the client so that it can best acquire and manage life cycle services in the future.

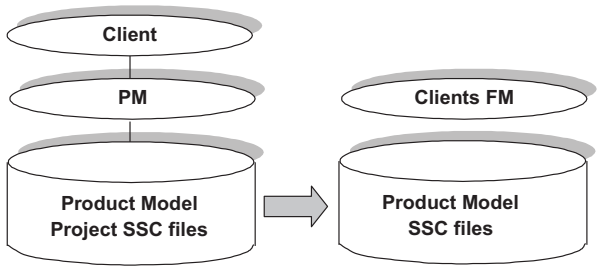

Figure 21. Commissioning and After-Sales Services Management System of the max VCMF.

(7) Network Nurturing Management System (NNMS)

Within the max VCMF, a lead member acts as a strategic centre and expects its network members to mutually follow rules and meet contractual obligations. **Involvement with network members** beyond traditional subcontracting includes several key issues such as developing member competencies, borrowing, developing and lending new ideas as well as sharing the perceptions of a competitive process and customer needs. The quality of relationships and the shared values also differentiate and define the soft boundaries of a network of SCCs (applying Tuomela 2004). Overall, a lead member manages and nurtures members in its competitive network in terms of three categories: (i) strategic SSCs that are awarded long-term arrangements as preferred members, (ii) non-strategic suppliers that are procured through more arms-length relationships, and (iii) only a few specialist suppliers that are also awarded long-term supply agreements, often on a single source basis (applying Cox & Townsend 1998).

A **network nurturing management system (NNMS)** enables a lead member of the VCMF to develop the competencies of its network in order to produce innovative building solutions both in short and longer terms (Figure 22). Building schemes are approached on a fit-for-purpose basis, i.e. required expertise and competencies are determined and necessary functional areas are specified for a focal project (Kiiras et al. 2010). Overall, high effectiveness is gained through providing key members with continuous workloads and improving synergic project performance along the joint principles of competence nurturing. On the one hand, special

concern is given to the avoidance of monopolistic dependency when nurturing network relationships. The max VCMF cannot become dependent on any single SSC. On the other hand, none of the SSCs is fully dependent on one particular VCMF. In other words, the former are encouraged to compete both individually and through other collaborative arrangements in other competitive arenas to gain more experience and knowledge of best practices. In turn, a special IIS provides a lead member with information for new member searches. Directories include information about preferred firms, their profiles (e.g. competencies, skills, performance history and in-house resources).

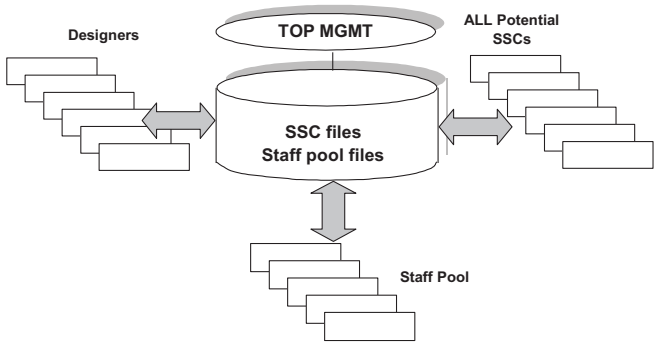

Figure 22. Network Nurturing Management System of the max VCMF

5. CONDUCT AND RESULTS OF THE BENCHMARKING OF THE FINNISH CM FIRMS RELATED TO VIRTUALITY AS DEFINED BY THE DESIGNED MODELS

In this chapter, the conduct and results of the benchmarking of the Finnish CM firms are reported upon in terms of adapting the max VCMF model to be used as a measurement tool, planning the benchmarking process (in terms of choosing the interview approach as well as selecting the case companies and the interviewees), designing the two interview questionnaires, collecting the empirical data (via the actual interviews), processing this empirical data and analysing the results.

5.1 Adaptation of the max VCMF model as a measurement tool

Aligning with Scholz (2000), a binary classification of organisations, virtual versus non-virtual, was not valid due to a fact that even traditional organisational forms exhibit at least some of the characteristics of the max VCMF. Moreover, it could be fairly safely assumed that there were no real-life companies in the focal context of the Finnish construction industry that would have exhibited many high degrees of the characteristics of the max VCMF (defined in section 4.2). Thus, a concept of gradual virtualisation is herein relied upon, i.e. case companies are classified according to their adoptions of virtual structures, respectively, on a continuous basis. That is, **the more virtual characteristics a firm exhibits, the higher its degree of virtuality (DV) is**. Moreover, Bauer & Köszegi's (2003) approach is adopted, i.e. the pre-assigned high degrees of virtuality of the max VCMF are used as the reference values for measuring the real DV of a firm. Accordingly, the max VCMF model was designed as a reference model for benchmarking and measuring companies' DV in the construction

industry. An underlying assumption is that all degrees of virtuality that companies are planning and realising can be captured within the three-dimensional space of managing, outsourcing and networking, so a firm's organisational transformations and dynamic interactions take place within this space (aligning with Venkatraman & Henderson 1998).

For the benchmarking, the max VCMF model was adapted to serve as a tool for measuring the DV of each case company. The max VCMF exhibits the preferred characteristics within the three-dimensional virtuality. The empirical measurement was focused as follows. Along the **first dimension** of an IT-based integrated network and project management system, the measurement detects the actual sub-degrees to which a firm uses ICT solutions to enable collaboration with its networked project parties and the management of business processes and projects. Along the **second dimension** of outsourcing operations and work, the measurement detects the actual sub-degrees to which a firm is developing and exploiting its core competencies (modularity) as well as outsourcing functional units, project organisations and construction work. Along the **third dimension** of collaboration with a competitive network, the measurement detects the actual sub-degrees to which a firm collaborates with networked SSCs and other parties, using contracts, rules and regulations to formalise relationships and enhancing trust within a network (Figure 23).

Along each (sub)dimension, the highest or maximum values were assigned to the characteristics of the max VCMF. Thus, the actually detected characteristics (values) of each case company could be compared with the highest characteristics (values) in order to identify levels, similarities and differences in virtuality among case companies. Each dimension of virtuality is detailed in terms of how the max VCMF performs virtually along this specific (sub)dimension. Its performance is defined in the statements and the maximum values of 5 (on a Likert scale of 1-5) are assigned to the VCMF in order to indicate its highest performance. In this way, each interviewee could rate the performance level of her or his case company and compare this with the VCMF's maximum performance level along the three dimensions of virtuality. The adapted (sub)dimensions are listed in detail in Questionnaires 1 and 2 (see Appendices 1 and 2).

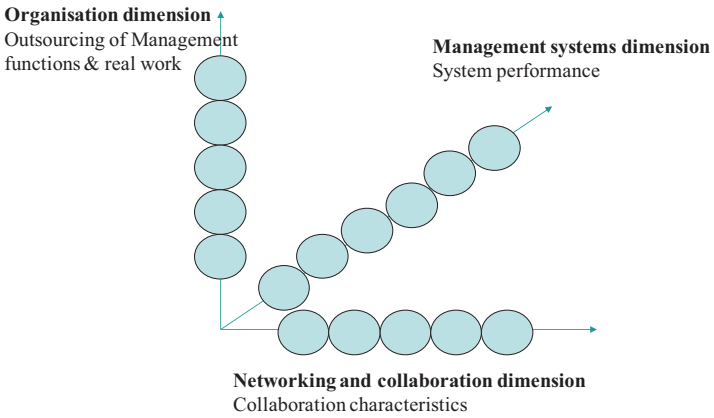

Figure 23. Max VCMF as an operation mode within the three-dimensional virtuality.

5.2 Planning of the benchmarking process

5.2.1 Planning the theme interviews with the Finnish case companies

The benchmarking task was tackled by using a **qualitative approach.** In this way, practitioners' perceptions of virtuality could be obtained. Ex ante, it was assumed that (i) virtuality as a phenomenon is not well understood among practitioners in the Finnish building industry and that (ii) virtuality is mainly linked to IT-based performance in projects. Thus, the benchmarking was planned to capture practitioners' thoughts and observations on this emerging phenomenon via the theme interviews, the face-to-face dialogues and the use of the self-assessment questionnaires.

The **semi-structured theme interviews** and the **face-to-face dialogues** were based on theme interview questionnaires covering the three-dimensional performance of the case companies. The sub-themes were approached with the open and semi-structured questions. In addition, the reliance on the **self-assessment questionnaires** enabled the interviewed practitioners to assess their companies' degrees of virtuality in a quantitative way against the highest characteristics of the max VCMF. In the self-assessment questionnaires, the same sub-themes were coupled with the statements on the highest performance of the max VCMF concerning each function and/or management process.

5.2.2 Selection of the ten case companies from the Finnish construction industry

The **criteria for choosing the case companies** were set purposefully, not randomly. The four selection criteria were rationalised as follows: (i) A non-homogenous mix of companies in the building industry was maintained so that the case companies represent both the main streams of contracting (general and CM services) and consulting. In addition, some case companies are engaged in international projects. (ii) The case companies represented different stages of company or business development, i.e. old traditional companies and fairly newly established entrepreneurs, in order to detect any differences in this area. (iii) The same six case companies that were interviewed during the exploratory interviews were also included in the theme interviews (this round revealed some important changes within the same companies). In addition, four new companies were added in order to capture any new insights in the detected sub-themes and to add some case companies for a comparative purpose. (iv) Ex ante, no fixed (large) number of the case companies was set. Instead, some companies were added in order to deepen the understanding of virtuality and its emergence in the focal context. The inclusion of new companies ceased when it was perceived that no new insights were to be found (applying Eisenhardt 1989).

In total, the **ten case companies from the Finnish construction industry** were included in the theme interviews. The case companies were approached and the data was collected over a period between June 2008 and January 2009 (Figure 24). There were the six construction contractors (Cases 1-3 and Cases 8-10), thereof the four contractors also acted as the CM contractors (Cases 1-2 and Cases 9-10) while the other two contractors acted as the general contractors (Case 3 and Case 8). One of these contractors was the international division (Case 10) of a Finnish construction corporation that operated in its targeted markets in Europe, the Middle East and Asia. In turn, the three consultants acted as the CM consultants (Case 4 and Cases 6-7) and the fourth consultant acted as the representative of clients (Case 5). Each case company was numbered according to the chronological order in the total interview process, which in turn depended on the time schedules offered by the interviewees to enable the participation.

5.2.3 Selection of the interviewees

The **two categories of the interviewees** were selected, i.e. the top management and the project (development) management. In this way, the theme interviews could result in the reliable collection of the company-specific facts and the perceptions of the multilevel decision-makers who were dealing with all aspects of the respective companies' management and had the first-hand knowledge of the strategies and the operations, including their possible virtuality. In addition, each manager could make an instant decision as to how far he or she could open up and hand over the company-specific, confidential information to the interviewer during the interview session(s). In

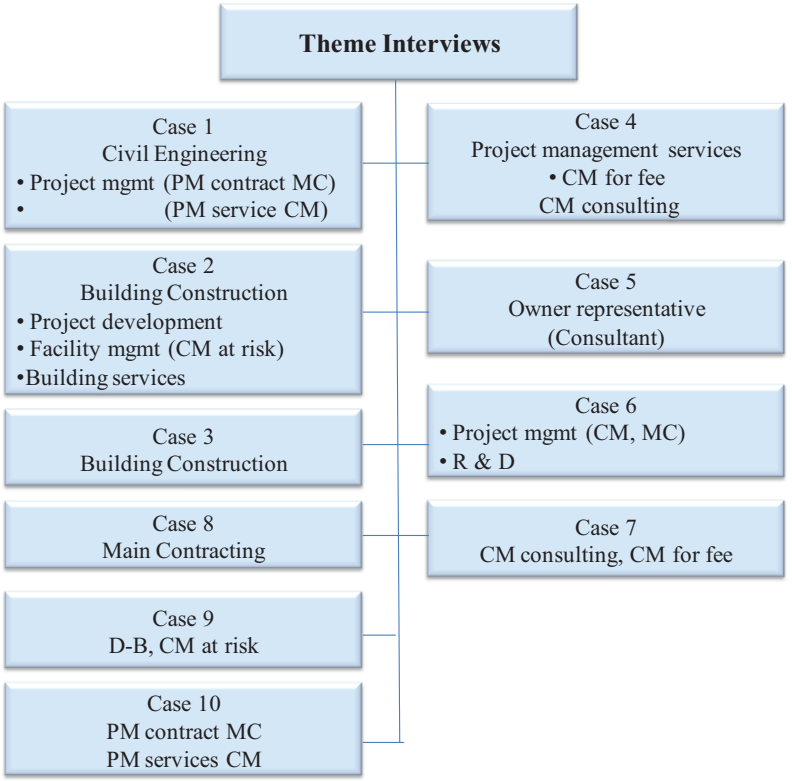

Figure 24. List of the ten case companies included in the theme interviews.

turn, the interviewer was able to structure the ten comparable, cross-sectional pictures and place each of them somewhere within the three-dimensional virtuality with the acceptable precision.

5.2.4 Design of the two questionnaires for the benchmarking

The researcher herself acted as the interviewer. For the benchmarking, the Finnish CM concepts were used to design the two sets of the questionnaires in order to collect the data through the theme interviews as follows.

Questionnaire 1 was designed for the **interviewer's own assessment.** It consisted of the detailed questions covering the three dimensions of virtuality. The interviewer used this questionnaire herself during the semi-structured interviews as the open, face-to-face dialogues with the top and project-level managers of the ten case companies. The interviewer collected the factual data and tried to encourage each interviewee to express her or his perceptions on how virtually their work was being performed. The interviewer also dealt with each interviewee's own views on her or his company's performance. The dialogues also shed light on the grey areas between possible YES and NO answers that the interviewees tended to use when their views either coincided or opposed the issues being investigated. For each dimension, the researcher/ interviewer planned many questions along each sub-dimension. Questionnaire 1 is attached to this report as **Appendix 1**.

Concerning the **first dimension**, the interviews were designed to detect how each company carried out its PM processes, how the network management was formally developed, how the network was actually managed, what compatible ICT systems and solutions were used to support project and network relations management with the members, the subcontractors, etc. in the case of each of the seven subsystems. The **questionnaires were designed** as follows:

- In the area of PORMS (sub-dimension 1.1), the purpose was to detect the reliance on 3D and product models when approaching clients' needs, the existence of IT-based directories listing current and potential clients, the existence of a special strategy to approach new clients, marketing schemes and follow-up in order to develop and maintain long-term client relationships.

- In the area of POBMS (sub-dimension 1.2), the purpose was to detect the degrees to which the case companies used project product models to prepare in-house WBSs, buy projects' BoQs and cost estimates as well as send and receive bid packages via the Internet to/from their contractors, subcontractors and SSCs per project.
- In the area of PDEMS (sub-dimension 1.3), the basis is the reliance on the project product models (or not). Therefore, the purpose was to detect the degrees to which the case companies had outsourced their project designs to be procured via product models and nowadays maintain product data libraries in in-house databases, and the degrees to which the companies involved contractors, subcontractors and SSCs in the detailed designs of bid packages.
- In the area of NPPMS (sub-dimension 1.4), the purpose was to detect the existence and use of the electronic lists of systems, processes and services to be packaged per project, the degrees to which the case companies had outsourced these and, thus, their reliance on the electronic lists for procuring such systems and services from among current and potential contractors and subcontracts.
- In the area of CPECMS (sub-dimension 1.5), the purpose was to detect the degrees to which the project process models (schedules) are used and developed based on the project product models, the use of any commercial or in-house developed software for cost control during project execution, and the degrees to which the case companies expect that contractors and subcontractors develop their package-specific schedules ahead of project execution and detailed activity plans during project execution to ensure proactive control.
- In the area of CASSMS (sub-dimension 1.6), the purpose was to detect how the case companies have arranged the provision of commissioning and FM services to clients, their reliance on specialised service providers and the submission of as-built project product models to clients in order to facilitate the effective life cycle management of their buildings.
- In the area of NNMS (sub-dimension 1.7), the purpose was to detect the use of IT-based directories that list and provide information about potential contractors and subcontractors and the tendency among the case companies to arrange training and allocate workloads to their preferred network partners in order to maintain long-term relationships.

Concerning the **second dimension**, the interviews were planned to cover (i) the outsourcing and employment of project organisations, teams, project managers, site managers and site engineers as well as (ii) the outsourcing of functional units and real work in terms of design services, work packages, bills of quantities and cost estimates, etc. The intent was to understand the possible outsourcing strategy that each case company practiced in more detail and to what extent the top management was willing or was planning to change and/or extend their outsourcing strategy in the future. Thus, the **questionnaires were designed** as follows:

- In the area of outsourcing project organisations and teams (sub-dimension 2.1), the purpose was to detect the degrees to which the case companies had outsourced project organisations and today rely on in-house project staff or recruit and hire them from external staff pools and other sources.
- In the area of outsourcing design and engineering services (sub-dimension 2.2), the purpose was to detect the degrees to which the case companies had outsourced design and engineering tasks and/or today procure such services based on (2D and 3D) designs as product models and whether they develop their product models based on in-house data libraries and databases.
- In the area of outsourcing project work packages (sub-dimension 2.3), the purpose was to detect the degrees to which the case companies had outsourced or today prepare in-house WBSs for projects by specifying the sizes and number of packages and relying on predefined lists of packages to be procured from predefined lists of (sub)contractors.
- In the area of outsourcing functional units (sub-dimension 2.4), the purpose was to detect the degrees to which the case companies had outsourced functional units or today handle in-house BoQs and cost estimates, project financing services and administrative work (book keeping, payrolls, etc.).

Concerning the **third dimension**, the interviews were planned to cover the development of actual core competencies, the preferred formal and informal collaboration as well as the role and development of trust. The questionnaires were designed as follows:

- In the area of collaboration with designers (sub-dimension 3.1), the purpose was to detect the case companies' collaboration strategies

related to networked A/Es, mutual, long-term relationships and recommendations to clients.

- In the area of collaboration with SSCs (sub-dimension 3.2), the purpose was to detect the case companies' collaboration strategies related to networked SSCs, contractors and subcontractors as well as long-term relationships in terms of arranging training and/or maintaining workloads.
- In the area of formal and informal relationships with networked SSCs and other parties (sub-dimension 3.3), the purpose was to detect the types of such relationships based on the case companies' own core competencies and procurement strategies (e.g. one-to-one, one-to-few or one-to-many), the extent of reliance on trust for maintaining long-term relationships.

Questionnaire 2 was designed for the **self-assessment by each interviewee**. It consisted of detailed, descriptive statements on how the max VCMF performs its functions and management processes fully virtually along each of the three dimensions of virtuality. The sub-dimensions were also covered to allow deeper reflection on the sub-degrees of virtuality. Each interviewee compared their company's management system and performance with those of the max VCMF on a Likert scale of 1 to 5. An interviewee was asked to use 1 (very low, non-virtual), if the company's system and performance did not match at all the stated, maximum way and to use 5 (very high, fully virtual), if the company's system and performance matched those of the max VCMF. The interviewees were asked to choose from within a range of 2 (low), 3 (average) and 4 (high), if the case company's system and performance mostly resembled little, average or much of the stated, maximum system and performance. Questionnaire 2 is attached to this report as **Appendix 2**.

Concerning the **first dimension**, the seven sub-dimensions were specified in terms of the respective areas of managing the max VCMF, enabled by the subsystems, i.e. (1.1) CRM, (1.2) project offering and bidding management, (1.3) project design and engineering management, (1.4) project procurement management, (1.5) project planning, execution and control management, (1.6) project commissioning and after-sales management, and (1.7) project network nurturing management. The interviewees were asked to assess (a) the existence of a network management subsystem besides the PM subsystem, (b) the performance of real-life management processes, (c) the extent of the use of ICT systems for

facilitating management processes, and (d) the use of building information models for integrating the seven management subsystems.

Concerning the **second dimension**, the four sub-dimensions were specified in terms of outsourcing (2.1) project organisations and teams, (2.2) design and engineering services, (2.3) project work packages and (2.4) functional units (project financing services, project administrative services and production planning). The interviewees were asked to assess (a) the extent of modularisation of project development processes and (b) the focus on the company's core competencies (after the outsourcing of other functions).

Concerning the **third dimension**, the three sub-dimensions were specified in terms of (3.1) the collaboration strategy with designers, (3.2) the collaboration strategy with SSCs or alike and (3.3) formal and informal relationships with network members. The three sub-dimensions involved the duration and configuration of cooperation with the member types. The interviewees were asked to assess (a) the degree of dependency between collaborative members (and project parties), (b) the formal and informal relationships, and (c) the atmosphere and degree of fairness and trust as a coordination mechanism between their network members (and project parties).

Questionnaire 2 was e-mailed to the interviewees and they were asked to complete their assessment after the interview session so that each interviewee could build her or his understanding of the max VCMF model and comprehend the actual assessments between this model and their own company.

The interviewer did not rate interviewees' answers during the interview sessions. Instead, the interviewer transcribed interviewees' replies and analysed the collected data. Thereafter, the interviewer rated each case company along each of the three dimensions of virtuality by using the same Questionnaire 2 that the interviewees were using to assess their companies against the max VCMF. In this way, the interviewer could **double-check** the self-ratings of the interviewees, respectively

5.3 Data collection via the theme interviews

Relying on Questionnaire 1, the interviewer could collect the case companies' fact-based states of virtual affairs and the interviewees'

perceptions on virtuality and virtual performance. In total, the researcher performed one interview per each of the ten case companies. The two interviews were conducted with the members of top management and the remaining eight interviews were with the project (development) managers. The durations of the interviews varied between 90 - 120 minutes. Each interviewee allowed the interviewer to use a tape recorder and record the data due to the time constraints. The interviewer transcribed all the recordings herself. Overall, the collected data consisted of the **facts** about case companies, the **interviewees' replies and perceptions** as well as the **interviewer's own company-specific ratings**.

Relying on Questionnaire 2, the interviewer could receive the interviewees' self-assessments via e-mail, where each of them compared their own company performance and the max VCMF's performance along each dimension of virtuality on a Likert 1-to-5 scale. The self-assessment scores of the interviewees were used as the primary, empirical evidence for the benchmarking because these scores are considered as the relevant, reflective, assessed degrees of virtuality of each case company. However, the interviewer double-checked the company-specific self-assessments of each interviewee against her own ratings and the interview data in order to identify any discrepancies. Ex post, the researcher had to inform one interviewee about the major discrepancies in their self-assessment scores, which was due to this interviewee's misinterpretation, i.e. the interviewee conducted a subjective assessment of the max VCMF's performance. Thus, the researcher has used her own scores for this case company as the eligible data.

5.4 Data processing, reporting and analysis

The **case company-specific ratings were processed** per each dimension of virtuality as follows:

(i) For each sub-dimension, the ratings of the statements were summed up and an average was calculated by dividing the sum by the number of the statements. When a statement contained many reflective sub-statements, a sum of these sub-statements' ratings was obtained first and an average rating was calculated by dividing the sum by the number of these sub-statements. Later, this **average rating was considered the main rating** of the statement in question and summed with the ratings of the rest of the statements under the same sub-dimension and an average rating

was obtained by dividing the sum by the number of statements under this sub-dimension.

(ii) For each main dimension; the average rating obtained for every sub-dimension was thereafter summed up with the average ratings of the other sub-dimensions along the same main dimension. In turn, an average rating for the main dimension was obtained by dividing the sum by the number of the sub-dimensions. This average score represented the DV of the case company along this main dimension of virtuality in comparison with the highest degree (of 5) of the max VCMF and those of the other case companies.

The processed, case company-specific data per each dimension of virtuality was further **reported** upon by compiling the two sets of tables as follows:

(i) For each sub-dimension, a descriptive three-column table was prepared to report on the results of the data processing step (1-i). The max VCMF and each case company (Case 1 … Case 10) were listed in the first column. The highest scores (5) of the max VCMF and the company-specific, average scores per each sub-dimension obtained from step (1-i) were presented in the second column. A brief explanation of the max VCMF's performance and the descriptions of each case company's performance (obtained from the interviews), regarding each sub-dimension, were presented in the third column (Appendix 3, Table 1). Figure 25, is an illustration of (Table 1) after the compilation with the scores processed in step (1-i).

(ii) A numeric table was compiled for the comparison between the case companies' ratings of the sub-dimensions for each of the three main dimensions of virtuality. The max VCMF and each case company (Case 1, …, Case 10) were placed on the upper row. Each sub-dimension was listed as well as the highest scores (5) of the max VCMF and the scores of each case company per each sub-dimension from (Step 1-i) were compiled into the respective columns. The similar tables were compiled concerning each of the three dimensions and their sub-dimensions of virtuality (Appendix 3, Table 2). Figure 26 is an illustration of (Table 2) compiled with the scores of the sub-dimensions of the three dimension of virtuality, respectively.

The results have been reported upon and analysed in the following section. The results are shown in the respective tables where the max VCMF's highest performance is followed with the assessment of each case company

(Case 1, ..., Case 10). The three dimensions of virtuality were shown in the first columns. The scores of each case company were presented at the intersection (Appendix 3, Table 3). The case company-specific results also enabled the conduct of the cross-case company analysis along each of the three dimensions of virtuality.

Company	Score	Description of company-specific virtuality/Sub-dimension 1.6
Max VCMF	**5.0**	A lead member outsources services to qualified SSC. It hands over updated as-built project product models to each client. It uses information collected from other management systems to find qualified SSCs to serve clients over the life cycles of their buildings.
Case 1	**2.0**	It offered no in-house or procured FM services for clients. It handed over as-built product models to clients.
Case 2	**1.0**	It offered no in-house or procured FM services for clients. It did not use as-built product models.
Case 3	**2.0**	It offered no in-house or procured FM services for clients. It handed over as-built product models to clients.
Case 4	**3.5**	It has an in-house FM system and it provides FM services to clients. It maintained two-year guarantee contracts with its subcontractors in order to continue their maintenance work. It checked on them.
Case 5	**1.0**	It offered no in-house or procured FM services for clients. It did not use as-built product models.
Case 6	**2.5**	It could perform in-house maintenance tasks. It provided clients with special, self-developed software to assist in the FM and maintenance of their buildings.
Case 7	**3.0**	It offered no in-house or procured FM services for clients. It provided clients with as-built drawings at the end of projects to assist with FM services.
Case 8	**3.5**	It offered clients FM services that it could procure from its network of subcontractors. It performed competitive bidding events to obtain FM management services contracts.
Case 9	**4.0**	It did not provide FM services to clients, but it assisted them in finding qualified service providers from its list of subcontractors. It handed out as-built product models to clients at end of projects.
Case 10	**1.5**	It offered no in-house or procured FM services for clients.

Figure 25. Illustration of (Table 1) compiled with the scores and a brief explanation of the sub-dimensions of virtuality processed in step (1-i).

3rd dimension Networking & collaboration	Max VCMF	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Collaboration strategy with designers	5.0	3.5	3.5	3.7	3.7	3.7	4.0	4.0	4.0	4.0	3.5
Collaboration strategy with special system contractors SSCs	5.0	2.0	3.0	3.3	3.3	2.5	3.0	3.0	3.5	2.7	2.5
Formal/informal relationships with competitve network members	5.0	3.5	3.3	3.0	3.5	3.5	3.3	3.0	3.2	3.6	3.8

Figure 26. Illustration of (Table 2) compiled with the scores of a sub-dimension of virtuality processed in step (1-i).

5.5 Results of the benchmarking process

5.5.1 Degrees of reliance on the seven management subsystems among the ten case companies (first dimension)

Along the first dimension, the IT-based integrated management system of the max VCMF consists of the seven subsystems (models) for managing a network and projects and the three-part BCIM. The **results of the assessed virtuality** of each of the ten case companies are herein presented by the seven sub-dimensions (subsystems):

(1.1) Project owner relation management subsystem (PORMS)

(1.2) Project offering and bidding management subsystem (POBMS)

(1.3) Project design and engineering management subsystem (PDEMS)

(1.4) Networked Project procurement management subsystem (NPPMS)

(1.5) Construction planning, execution and control management subsystem (CPECMS)

(1.6) Commissioning and after-sales services management subsystem (CASSMS)

(1.7) Network nurturing management subsystem (NNMS).

In Table 3, the **assessed virtuality of PORMS (1.1)** of each of the ten case companies is presented. A range of the average scores was 2.0-4.2. The most virtualised company (Case 9 with 4.2) used a self-developed CRM database, product models to meet clients' requirements as well as advanced marketing schemes, fairs and follow-ups to build long-term relationships. The analysis of the data collected from the case companies' responses

shows the existence of the lists for current and in some cases potential clients in most of the case companies, yet the subsystem is not used in an efficient or systematic way in order to draw a strategy for approaching new clients, because in most cases the companies wait for their clients to approach them for any new projects. Only some case companies considered approaching clients as their planned strategy to obtain new projects. On the other hand, follow-up surveys, fairs and marketing schemes are becoming a vital part of the companies' strategies towards maintaining long-term client relationships.

In Table 4, the **assessed virtuality of POBMS (1.2)** of each of the ten case companies is presented. A range of the average scores was 2.0-4.0, which indicates an average virtual performance mainly because even though some companies have become accustomed to buying/outsourcing bills of quantities from special consultants, all the companies consider cost estimation as their core competence and note that they would continue to prepare in-house WBSs (based on the outsourced or their own product models) and cost estimates. Also, the majority of the case companies admitted that the non-compatible IT systems of subcontractors hindered IT-based communication such as sending and receiving bids via the Internet.

In Table 5, the **assessed virtuality of PDEMS (1.3)** of each of the ten case companies is presented. A range of the average scores was 2.0-4.0. The eight more virtual companies (with 2.7-3.7) procured 3D designs and converted them in-house to product models by using special architectural design software such as ArchiCAD, or they procured product models from their networks of architects and engineers. Companies that rated below (2.7) were those that continued to outsource design drawings in 2D. The main finding is that almost all the companies were eagerly experimenting with external product models in their pilot projects, but only very few had created product modelling libraries for their in-house usage. It is still a long way from being highly virtual in this area.

In Table 6, the **assessed virtuality of NPPMS (1.4)** of each of the ten case companies is presented. A range of the average scores was 2.7-4.2, which can be considered average to high, mainly because the case companies considered that the creation and maintaining of the lists of systems and services to be procured was important for their efficient project development. In addition, the keeping of the up-to-date lists of their

contractors and subcontractors was very important for obtaining qualified project partners to match procured project services and systems.

In Table 7, the **assessed virtuality of CPECMS (1.5)** of each of the ten case companies is presented. A range of the high average scores was 3.0-4.3 because nearly all the companies were using advanced IT software and systems for project planning, scheduling and control processes. In addition, the companies were eager to connect their planning and scheduling systems with cost estimation systems via newly developed cost estimation software for better cost control. An interesting finding was that the companies were more eager to develop their core competencies for in-house cost estimation, including the use of new software (bought from the market) rather than to outsource this function and procure services from specialised consultants.

In Table 8, the **assessed virtuality of CASSMS (1.6)** of each of the ten case companies is presented. A range of the average scores was 1.0-4.0. The case companies differed significantly. The relatively high scores of the four CM and PM consultants were 2.5-3.5, because each of them assisted their clients in relation to commissioning tasks and as-built product models. In reality, the five CM and other contractors could not provide or outsource/procure commissioning services for clients, which explains their low virtuality scores. One CM contractor (Case 9) was the exception when it assisted clients in buying such services and handing over as-built product models to clients.

In Table 9, the **assessed virtuality of NNMS (1.7)** of each of the ten case companies is presented. A range of the average scores was 2.5-4.0. Only one company scored 4.0. Each of the ten case companies were engaged in electronic directories listing and providing information on potential contractors and subcontractors. Only a couple of them used the subsystem to rank their network members according to their performance for future jobs selection. Instead, only one company provided training and workloads for its preferred network members to maintain long-term relationships. They admitted the possibility of saving some potential works for their preferred network members.

In Table 10, the **average, first dimension-specific scores** and the underlying sub-scores of each of the ten case companies along the seven sub-dimensions (subsystems in managing) of virtuality are presented. A range of these scores along the first dimension of IT-based, integrated management system was 2.6-4.0. The highest score of 4.0 was assessed to

be with Case 9 (D-B and CM-at-risk contractor). The same range is illustrated in Figure 27.

Table 3. Assessed virtuality among the ten case companies in the area of project owner relationship management subsystem (PORMS).

Company	Score	Description of company-specific virtuality/Sub-dimension 1.1
Max VCMF	**5.0**	The design and virtualisation of client needs is approached by product models. Management is also involved in seeking new clients. Special marketing schemes are used for maintaining long-term client (project owner) relations.
Case 1	**4.0**	Client needs were addressed by 3D, not product models. A database of current and potential clients was used. Management approached new clients with investments in mind to develop their projects.
Case 2	**2.5**	Client needs were approached by 3D, not product models. An Excel list of current and potential clients was used. Marketing schemes were used for long-term client relations. Company did not actively contact clients.
Case 3	**4.0**	Client needs were approached by 3D, not product models. A database of current and potential clients was used. Marketing schemes & follow-up surveys were used for long-term client relations. Own reputation was used to attract new clients.
Case 4	**3.0**	Client needs were approached by 3D, not product models. An Excel list of current and potential clients was used. Marketing schemes and follow-up surveys were used for long client relations. Company did not actively contact clients.
Case 5	**3.7**	Client needs were approached by 3D, not product models. An Excel list of current and potential clients was used. Marketing schemes were used to maintain long-term relations. Top management approached new clients.
Case 6	**2.0**	Client needs were approached by 3D, not product models. An Excel list of current and potential clients was used. No marketing schemes were used to maintain relations. Company did not actively contact new clients.
Case 7	**3.2**	Client needs were approached by product models when required. An electronic, advanced PORMS was used. Marketing schemes were used for long-term relations. Company management approached new clients.
Case 8	**3.5**	Client needs were approached by product models when required. An electronic, advanced PORMS was used. Marketing schemes were used for long-term relations. Company management approached new clients.
Case 9	**4.2**	Client needs were approached by product models. A database of current and potential clients was used. Marketing schemes and after-sales, follow-up surveys were used for long-term client relations. Project development department approached new clients, project managers approached existing clients.
Case 10	**3.0**	Clients were not approached by product models. There was no advanced PORMS as company's clients were limited local companies with international projects. Head of a company and his deputy approached new clients. No marketing schemes were used. Only subscriptions to professional journals were used for client information.

Table 4. Assessed virtuality among the ten case companies in the area of projec offering and bidding management subsystem (POBMS).

Company	Score	Description of company-specific virtuality/Sub-dimension 1.2
Max VCMF	**5.0**	A lead member prepares WBSs based on an outsourced product model, bought BoQs and cost estimates, distributes and receives bid packages to/from SSCs via the Internet and decides upon SSCs' bids.
Case 1	**3.0**	It prepared WBSs from the outsourced product model (Tocoman TCM). It prepared in-house BoQs and tender prices based on the product model. Cost control was based on COSMA. No works were carried out with SSCs.
Case 2	**2.3**	It prepared WBSs by using the in-house 3D model, bought BoQs, prepared own cost estimates by using the in-house resource and cost libraries. It had a network of contractors and suppliers.
Case 3	**3.7**	It prepared in-house WBSs based on the outsourced product model as well as BoQs and cost estimates. It had the network of subcontractors and suppliers.
Case 4	**2.0**	It prepared WBSs by using in-house the 3D models, bought or prepared in-house BoQs depending on CM services and made in-house cost estimations. It considered large bid packages to work with SSCs.
Case 5	**2.3**	Its QM system contained the models for calling bids (not electronically). It prepared in-house WBSs, BoQs and cost estimates. It called for bids among the network of contractors and suppliers.
Case 6	**3.3**	It prepared WBSs by using the self-developed software to retrieve information from outsourced 3D models. It prepared in-house BoQs and cost estimates. It sent and received bids electronically.
Case 7	**3.0**	It prepared in-house WBSs by using the 3D models, bought or prepared in-house BoQs depending on CM services. It had outsourced cost estimation. It called for bids among the network of contractors and suppliers.
Case 8	**3.7**	It prepared in-house WBSs based on the outsourced product model. It prepared in-house BoQs and cost estimates. It distributed bid packages among subcontractors and/or SSCs depending on package sizes and prices via the Internet.
Case 9	**4.0**	It prepared in-house WBSs by using the outsourced product model. It prepared in-house BoQs and cost estimates. It distributed and received bid packages electronically. It worked with subcontractors and SSCs.
Case 10	**2.7**	The international, localised organisation (unit) of the case company prepared WBSs by using the outsourced product model. It prepared in-house BoQs and cost estimates that were approved by the head office in Finland. It sent and received bids electronically to/from subcontractors.

Table 5. Assessed virtuality among the ten case companies in the area of project design and engineering management subsystem (PDEMS).

Company	Score	Description of company-specific virtuality/Sub-dimension 1.3
Max VCMF	**5.0**	A lead member uses an outsourced product model of an A/E company to serve its competitive network. A product model is accessed by SSCs for detailed designs and updates by bid packages.
Case 1	**3.0**	It procured 2D and 3D designs from its A/E network. It converted in-house 2D and 3D designs to product models by ArchiCAD. It selected A/E companies based on bidding processes.
Case 2	**2.0**	It procured 2D and 3D detailed designs from its A/E network (no product modelling). It used in-house ArchiCAD for design checks. It selected A/E companies based on bidding process.
Case 3	**3.7**	It procured the product models from its A/E network. It kept partnering agreements with A/Es in residential development. It used in-house ArchiCAD, TEKLA and MagiCAD for design checks and quantity take-offs.
Case 4	**2.7**	It procured 3D designs from its A/E network (no product models). It prepared competitive bidding events between A/Es so that clients could make final selections. It used in-house ArchiCAD for 3D design checks.
Case 5	**2.7**	It maintained the network of A/Es with long work histories. It recommended A/E companies for clients that could make selections based on qualifications. Design contracts were made directly between A/Es and clients. It used in-house 2D and 3D designs.
Case 6	**3.7**	It procured 3D designs and product models based on project types. It performed in-house design management, kept the product models on the server to share information with project stakeholders. It recommended A/Es from its network to clients for their final selections. It used in-house ArchiCAD, TEKLA and MagiCAD for design checks and quantity take-offs.
Case 7	**3.3**	It procured 3D designs and product models based on project types. It performed in-house design management. It recommended A/Es from its network to clients for their final selections. It used in-house ArchiCAD and TEKLA for design checks and quantity take-offs.
Case 8	**4.0**	It procured product models from its network of A/Es. It had self-developed product model libraries. It arranged competitive bidding events when selecting A/Es. It used in-house ArchiCAD and had self-developed the structural design software for design checks and quantity take-offs.
Case 9	**3.7**	It procured product models from its network of A/Es. It performed in-house design management. It maintained SSCs' inputs to product models during detailed designs.
Case 10	**2.3**	It procured 3D designs from its Finnish and international network of A/Es depending on projects and client requirements. It also procured product models based on client requirements.

Table 6. Assessed virtuality among the ten case companies in the area of networke project procurement management subsystem (NPPMS).

Company	Score	Description of company-specific virtuality/Sub-dimension 1.4
Max VCMF	**5.0**	A lead member outsources processes and services which are not its core competencies. A system provides a list of processes and services to be procured and a list of current and potential qualified SSCs.
Case 1	**2.7**	It prepared in-house WBSs per project. It did not maintain a list of work packages to be procured. It maintained and updated an electronic list of (sub)contractors to be procured.
Case 2	**3.0**	It prepared in-house WBSs per project. It maintained a list of systems, processes and services to be procured. It maintained and updated an electronic list of (sub)contractors and SSCs to be procured.
Case 3	**3.0**	It prepared in-house WBSs per project. It maintained and updated a list of systems and services to be procured. It maintained a list of SSCs. It developed frame agreements with big material suppliers. It used two pieces of self-developed software for procurement management.
Case 4	**3.0**	It prepared in-house WBSs per project. It maintained a predefined list of work packages to be procured. It maintained and updated an electronic list of subcontractors to be procured. It procured separately material suppliers and work contractors.
Case 5	**3.0**	It maintained discussions with CM contractors in projects concerning its WBS and the preparation of procurement packages. It suggested subcontractors to clients for their final selections.
Case 6	**4.0**	It prepared in-house WBSs per project according to the predefined lists of packages. It used self-developed software. It maintained and updated an electronic list of (sub)contractors to be procured.
Case 7	**3.3**	It prepared in-house WBSs per project. It maintained a list of systems, processes and services to be procured. It maintained and updated an electronic list of (sub)contractors and SSCs to be procured.
Case 8	**4.0**	It prepared in-house WBSs per project. It maintained a list of special packages to be procured. It maintained and updated a list of (sub)contractors to be procured. It kept annual agreements with SSCs to work on special packages.
Case 9	**4.2**	It prepared in-house WBSs per project. It maintained a list of work packages to be procured. It maintained and updated a list of suppliers and (sub)contractors to be procured. It preferred compatible contractors who could work with product models.
Case 10	**3.0**	Its project organisations procured WBSs and project packages in the foreign country. The sizes and number of bid packages depended on project sizes and types, but it mainly compiled large packages to attract large contractors.

Table 7. Assessed virtuality among the ten case companies in the area of construction planning, execution and control management subsystem (CPECMS).

Company	Score	Description of company-specific virtuality/Sub-dimension 1.5
Max VCMF	**5.0**	A lead member prepares a process model based on a product model for a project in term of systems and packages to be performed by SSCs. SSCs prepare the detailed activity plans/schedules as part of their bid packages. It feeds design changes and cost information into a process model for updating schedules and cost control.
Case 1	**4.0**	It prepared in-house master plans and schedules for each phase of projects with VICO Control. Subcontractors prepared their detailed package schedules. Self-developed software was used for cost control.
Case 2	**3.0**	It prepared in-house milestone schedules with PlaNet+ software. It assisted subcontractors with their detailed schedules. It used in-house TOCOMAN for cost control.
Case 3	**3.7**	It prepared in-house master schedules. Subcontractors prepared and integrated detailed packages' schedules with master schedules. It prepared detailed activity schedules with subcontractors. It used in-house DynaProject and Vick Control for planning and scheduling control. It controlled costs in-house with Tocoman and it also used self-developed software.
Case 4	**4.0**	In CM consulting, it prepared in-house master schedules for main contractors with MS Project. Subcontractors prepared and integrated their detailed schedules. In CM for fee contracts, it prepared subcontractors' master schedules. Subcontractors prepared detailed activity schedules. It controlled costs in-house with CM Pro software.
Case 5	**3.3**	It performed in-house design management for clients to maintain design schedules with designers. General or CM contractors got involved in design, depending upon when they were hired.
Case 6	**4.3**	It prepared in-house master schedules based on Line of Balance (LoB) with DynaProject. Subcontractors prepared detailed schedules and integrated them. It used self-developed software for cost control.
Case 7	**3.5**	It prepared in-house master schedules based on the main tasks or packages of subcontractors that prepared detailed schedules and integrated them with master schedules.
Case 8	**3.7**	It prepared in-house master schedules based on main tasks or packages with PlaNet. Subcontractors prepared detailed schedules and integrated them with master schedules. It used self-developed software for cost control.
Case 9	**4.3**	It prepared in-house master schedules. Subcontractors prepared and integrated detailed schedules with master schedules. It could assist if some subcontractors could not perform alone. It used self-developed software for cost control.
Case 10	**3.0**	Its project organisations abroad prepared master schedules. Subcontractors prepared and integrated detailed schedules with master schedules. Subcontractors also prepared detailed activity schedules three weeks ahead during construction works. It used self-developed software for cost control.

Table 8. Assessed virtuality among the ten case companies in the area of commissioning and after-sales services management subsystem

Company	Score	Description of company-specific virtuality/Sub-dimension 1.6
Max VCMF	**5.0**	A lead member outsources services to qualified SSC. It hands over updated as-built project product models to each client. It uses information collected from other management systems to find qualified SSCs to serve clients over the life cycles of their buildings.
Case 1	**2.0**	It offered no in-house or procured FM services for clients. It handed over as-built product models to clients.
Case 2	**1.0**	It offered no in-house or procured FM services for clients. It did not use as-built product models.
Case 3	**2.0**	It offered no in-house or procured FM services for clients. It handed over as-built product models to clients.
Case 4	**3.5**	It has an in-house FM system and it provides FM services to clients. It maintained two-year guarantee contracts with its subcontractors in order to continue their maintenance work. It checked on them.
Case 5	**1.0**	It offered no in-house or procured FM services for clients. It did not use as-built product models.
Case 6	**2.5**	It could perform in-house maintenance tasks. It provided clients with special, self-developed software to assist in the FM and maintenance of their buildings.
Case 7	**3.0**	It offered no in-house or procured FM services for clients. It provided clients with as-built drawings at the end of projects to assist with FM services.
Case 8	**3.5**	It offered clients FM services that it could procure from its network of subcontractors. It performed competitive bidding events to obtain FM management services contracts.
Case 9	**4.0**	It did not provide FM services to clients, but it assisted them in finding qualified service providers from its list of subcontractors. It handed out as-built product models to clients at end of projects.
Case 10	**1.5**	It offered no in-house or procured FM services for clients.

Table 9. Assessed virtuality among the ten case companies in the area of network nurturing management subsystem (NNMS).

Company	Score	Description of company-specific virtuality/Sub-dimension 1.7
Max VCMF	**5.0**	A lead member assists its collaborative network in developing their core competencies. It provides them with workloads. It develops electronic directories including information about current and potential companies, their profiles, performance histories and competencies.
Case 1	**3.0**	It neither assisted in developing core competencies, nor arranged workloads to its collaborative network of contractors. It maintained the database of current and potential contractors with the self-developed software.
Case 2	**3.0**	It neither assisted in developing core competencies, nor arranged workloads to its collaborative network of contractors. It maintained the database of current and potential contractors with the self-developed software.
Case 3	**2.7**	It maintained and updated the database of its competitive network of SSCs. It did not assist in developing their core competencies, but it expected innovative solutions. It maintained framework agreements with material suppliers.
Case 4	**2.5**	It neither assisted in developing core competencies, nor arranged workloads to its collaborative network of contractors. It maintained and updated the list of current and potential contractors with MS Office.
Case 5	**2.7**	It neither assisted in developing core competencies, nor arranged workloads to its collaborative network of contractors. It maintained and updated the list of current and potential contractors with MS Office.
Case 6	**2.5**	It did not assume any responsibility towards its network of contractors and subcontractors. It maintained and updated the database of current and potential contractors with the self-developed software.
Case 7	**2.5**	It did not assist in developing the competencies of its collaborative network of contractors. As a consultant, it did not arrange workloads. It maintained and updated the list of current and potential contractors with MS Office.
Case 8	**3.0**	It neither assisted in developing core competencies, nor arranged workloads to its collaborative network of contractors. It maintained and updated the list of current and potential contractors and suppliers with the self-developed software.
Case 9	**4.0**	It can give advice to its SSCs for the development of their core competencies, but it did not provide subcontractors and suppliers with workloads. It maintained and updated the electronic list of current and potential contractors.
Case 10	**2.5**	Its local office in the foreign county did not assist in developing core competencies. This office did not arrange workloads to its collaborative network of contractors. It maintained and updated the electronic list of current and potential contractors.

Table 10. Comparison of the assessed average virtuality of the ten case companies along the first dimension of the IT-based network and project management system.

	1st dimension management Subsystems	Max VCMF	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Firm management	Client relations Management	5.0	4.0	2.5	4.0	3.0	3.7	2.0	3.2	3.5	4.2	3.0
	Network nurturing management	5.0	3.0	3.0	2.7	2.5	2.7	2.5	2.5	3.0	4.0	2.5
	Commissioning & After sales management	5.0	2.0	1.0	2.0	3.5	1.0	2.5	3.0	3.5	4.0	1.5
Project management	Offering& bidding management	5.0	3.0	2.3	3.7	2.0	2.3	3.3	3.0	3.7	4.0	2.7
	Design&engineing management	5.0	3.0	2.0	3.7	2.7	2.7	3.7	3.3	4.0	3.7	2.3
	Networked project Procurement management	5.0	2.7	3.0	3.0	3.0	3.0	4.0	3.3	4.0	4.2	3.0
	Construction planing Execusion &control management	5.0	4.0	3.0	3.7	4.0	3.3	4.3	3.5	3.7	4.3	3.3

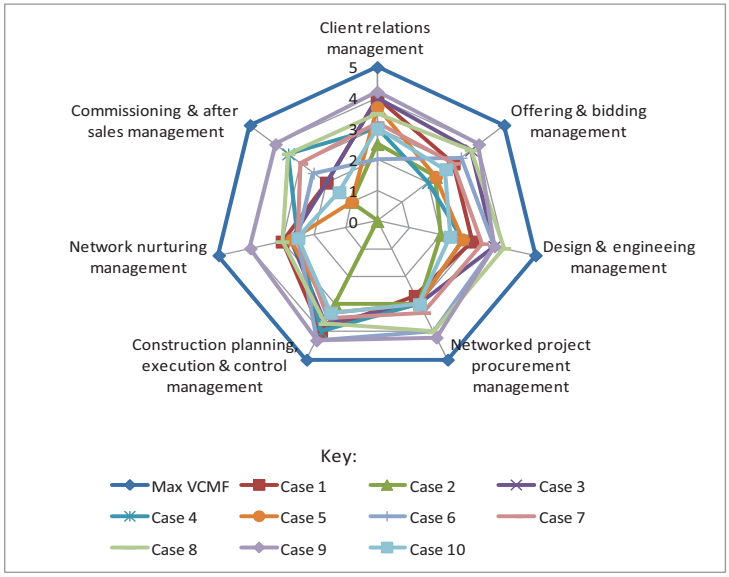

Figure 27. Range of the assessed virtuality of each of the ten case companies along the first dimension of IT-based management system, by the

5.5.2 Degrees of the outsourced operations and work among the ten case companies (second dimension)

Along the second dimension, outsourcing of operations and work of the max VCMF consists of the four sub-dimensions. The **results of the assessed virtuality** of each of the ten case companies are herein presented under these four sub-dimensions:

(2.1) Outsourcing of project organisations and teams

(2.2) Outsourcing of design and engineering services

(2.3) Outsourcing of project work packages

(2.4) Outsourcing of functional units (project financing services, project administrative services and production planning).

In Table 11, the **assessed virtuality of outsourced project organisations and teams (2.1)** of each of the ten case companies is presented. A range of the fairly low scores (2.0-3.0) was due to a fact that all the companies wanted to maintain a permanent, experienced staff in order to guarantee quality performance and prevent getting into bottlenecks due to a lack of experienced people. Case company 10, which had the highest score (3.0), was an international division of a corporation that had to outsource its project staff from the local foreign market of its operations, as the company could not afford keeping a permanent project staff abroad due to uncertainty of project availability in the long term.

In Table 12, the **assessed virtuality of outsourced design and engineering services to A/Es (2.2)** of each of the ten case companies is presented. A range of the average scores was high (3.0-4.0) because most companies had outsourced designs and they were very eager to experiment and work with product models. This was because Finnish and other Nordic contractors and consultants mainly procured design and engineering services from among specialised A/Es, even in the case of D-B contractors and developers.

In Table 13, the **assessed virtuality of outsourced project work packages (2.3)** of each of the ten case companies is presented. A range of the average scores was 3.0-3.6. Cases 3-6 and 9-10 with the scores of 3.5 perceived that breaking down projects into large work packages was a viable strategy that in turn attracted competent SSCs to submit their competitive bids.

In Table 14, the **assessed virtuality of the outsourced functional units (2.4)** of each of the ten case companies is presented. A range of the average scores was 2.0-3.7. Only Case 10 (the international division) with the highest score of 3.7 had clearly outsourced its functional units and today procured these services from the local market in the foreign country instead of keeping permanent Finnish staff in foreign subsidiaries. Most companies were managing their functions that were performed by the networks of both in-house and external units. The companies considered the cost estimation as their respective core competencies and preferred to continue like this. Recently, they had started to outsource only the preparation of BoQs. Thus, most companies were rated with the rather low average scores between 2.0- 2.7.

In Table 15, the **average, second dimension-specific scores** and underlying sub-scores of each of the ten case companies along four sub-dimensions of virtuality are presented. A range of these scores along the second dimension of outsourcing of operations and project work was 2.6-3.5. The highest score of 3.5 was assessed to be with Case 10 (the international division of the Finnish contractor). The same range is illustrated in Figure 28.

Table 11. Assessed virtuality among the ten case companies in the area of outsourcin project organisations and teams.

Company	Score	Description of company-specific virtuality/Sub-dimension 2.1
Max VCMF	**5.0**	A lead member appoints project managers from its staff at the start of projects. It uses outsourced project teams (site managers and site engineers) from a pool of former staff.
Case 1	**2.0**	It suggested project organisations (including in-house project managers, site managers and site engineers) to clients at the beginning of projects. Clients made final approvals.
Case 2	**2.0**	It assigned project organisations (including project managers, site managers, site engineers and other team members) from the in-house staff pool.
Case 3	**2.0**	It assigned project organisations (including project managers, site managers, site engineers and other team members) from the in-house staff pool.
Case 4	**2.2**	Its top management controlled the in-house staff pool, appointed project managers who in turn appointed in-house site managers, site engineers and other team members.
Case 5	**2.0**	Its senior management team managed work on projects and this team hired supervisors from the market.
Case 6	**2.2**	It maintained the in-house project teams (project managers, site managers and site engineers) as its permanent workforce.
Case 7	**2.0**	Its top management appointed project managers who in turn appointed in-house site managers, site engineers and other team members.
Case 8	**2.0**	It maintained the in-house project teams (project managers, site managers and site engineers) as its permanent workforce.
Case 9	**2.0**	It maintained the in-house project teams (project managers, site managers and site engineers) as its permanently contracted workforce.
Case 10	**3.0**	Its international division had permanent staff including project managers. Its head office also took part in appointing project teams (site managers and site engineers) from within the external staff pools in the local market in the foreign country.

Table 12. Assessed virtuality among the ten case companies in the area of outsourcing design and engineering services.

Company	Score	Description of company-specific virtuality/Sub-dimension 2.2
Max VCMF	**5.0**	A lead member uses outsourced design and engineering services from its competitive network of architects and designers. It uses project product models for bidding or negotiation.
Case 1	**3.0**	It had outsourced design and engineering and had procured these services through bidding processes among architects and designers with whom it had long work histories. It procured designs externally as 2D and converted them in-house to 3D with ArchiCAD.
Case 2	**3.2**	It had outsourced 2D and 3D detailed designs and procured them from its network of A/Es. It converted in-house designs to product models with ArchiCAD. It selected A/Es by bidding processes.
Case 3	**3.5**	It had outsourced designs and entered partnering agreements with A/Es in the residential sector. Otherwise, it could recommend these A/Es to clients for their projects. It used ArchiCAD, MagiCAD and TEKLA for design checks and quantity take-offs.
Case 4	**3.0**	As a consultant, it had outsourced designs and procured A/Es' services via bidding processes for clients. Clients made final selections. It procured 3D designs, but it used in-house ArchiCAD for 3D design checks.
Case 5	**3.0**	As a consultant, it had outsourced 3D design and procured these services via bidding processes among A/Es for clients. Clients made final decisions and held contracts with A/Es.
Case 6	**4.0**	As a consultant, it had outsourced design and engineering and procured these services via bidding processes for clients. It recommended A/Es from within its network to clients for final selection. It procured 3D designs and product models. It used in-house ArchiCAD, TEKLA and MagiCAD for design checks and quantity take-offs.
Case 7	**4.0**	As a consultant, it had outsourced 3D design and today procured these services via bidding processes for clients. It procured product models based on project types. It used in-house ArchiCAD, TEKLA and MagiCAD for design checks and quantity take-offs.
Case 8	**4.0**	It had outsourced design and procured these services from its network of A/Es. It arranged competitive bidding processes for selections. It procured product models. It had its self-developed data model libraries. It used in-house ArchiCAD and the self-developed software for design checks and quantity take-offs.
Case 9	**4.0**	It had outsourced design and procured these services from its network of A/Es via bidding processes. It also procured product models for designs.
Case 10	**4.0**	It had outsourced design and procured these services from its network of Finnish and international A/Es via bidding processes. It procured designs as 3D and sometimes as product models based on client requirements.

Table 13. Assessed virtuality among the ten case companies in the area of outsourcin project work packages.

Company	Score	Description of company-specific virtuality/Sub-dimension 2.3
Max VCMF	**5.0**	A lead member prepares in-house project WBSs, outsources all processes and services which are not its core competencies. It relies on a list of potential and qualified SSCs.
Case 1	**3.0**	It prepared in-house WBSs, but did not keep the list of work packages to be procured. It procured work packages from the list of (sub)contractors maintained in the electronic form.
Case 2	**3.2**	It prepared in-house WBSs according to the list of processes and systems to be procured. IT actually procured them with the list of (sub)contractors with whom it had long work histories.
Case 3	**3.5**	It prepared in-house WBSs per project. It procured work packages according to the list of systems and services from within its network of contractors and SSCs.
Case 4	**3.5**	It prepared in-house WBSs per project. It procured work packages according to a predefined list of contractors and subcontractors.
Case 5	**3.5**	As a consultant, it maintained discussions with CM contractors concerning its WBSs and work packages. It procured work packages from among (sub)contractors after clients' approvals.
Case 6	**3.5**	It prepared in-house WBSs, but not necessarily according to a predefined list of packages. It procured work packages via its network of subcontractors with whom it had long work histories.
Case 7	**3.2**	It prepared in-house WBSs and work packages to be procured per project. It procured work packages according to the list of contractors and subcontractors.
Case 8	**3.6**	It prepared in-house WBSs per project. The size and number of work packages differed per project. Some packages were procured from SSCs with whom it maintained special agreements.
Case 9	**3.5**	It prepared in-house WBSs. It maintained the list of work packages and procured them from contractors with whom it had long work histories and who specialised in performing specified works.
Case 10	**3.5**	Its project organisation abroad prepared in-house WBSs. It used a special list of work packages for the preparation of the sizes and number of these packages. It kept package sizes large in order to attract SSCs.

Table 14. Assessed virtuality among the ten case companies in the area of outsourcing functional units.

Company	Score	Description of company-specific virtuality/Sub-dimension 2.4
Max VCMF	**5.0**	A lead member outsources all functional units including project financing and administrative services, BoQs, cost estimation and project production planning and scheduling.
Case 1	**2.4**	It had outsourced financing services, but performed in-house project administrative services. It prepared in-house WBSs cost estimates, but bought BoQs. Subcontractors prepared their production plans.
Case 2	**2.4**	It had outsourced financing services, but performed in-house project administration. It prepared in-house WBSs and cost estimates, but bought BoQs. Subcontractors prepared their production plans.
Case 3	**2.5**	It had in-house project financing, but it had outsourced financial services. It performed in-house project administrative services. It prepared in-house WBSs and cost estimates, but bought BoQs. Subcontractors prepared their production plans.
Case 4	**2.2**	As a consultant, it did not interfere with financing. It performed in-house project administrative services as well as the preparation of WBSs, BoQs and cost estimates. It expected that subcontractors prepared their production plans.
Case 5	**2.0**	As a consultant, it did not interfere with project financing. It performed in-house project administrative services, BoQs and cost estimates. It expected that subcontractors prepared their production plans.
Case 6	**2.5**	As a consultant, it did not interfere with financing. It had outsourced bookkeeping and the preparation of balance sheets. It prepared in-house WBSs, BoQs, cost estimates and project production plans.
Case 7	**2.2**	As a consultant, it did not interfere with project financing. It performed in-house project administrative services. It prepared in-house cost estimates, but bought BoQs. It expected that subcontractors prepared their production plans.
Case 8	**2.7**	It had outsourced financial services. It performed in-house project administrative services and the preparation of WBSs, BoQs and cost estimates. It expected that subcontractors prepared their production plans.
Case 9	**2.5**	It had outsourced financial services. It performed in-house project administrative services and the preparation of BoQs and cost estimates. Subcontractors prepared their production plans.
Case 10	**3.7**	It had outsourced financial services. Clients financed their projects. It had outsourced administrative services and today procured them from the local market in the foreign country. It kept its in-house staff. Sometimes it bought BoQs. It prepared in-house WBSs and cost estimates. Subcontractors prepared their production plans.

Table 15. Comparison of the assessed average virtuality of the ten case companies along the second dimension of the outsourcing of operations and project work, by the four sub-dimensions.

2nd dimension Outsourcing functional units & real work	Max VCMF	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Outsourcing project organisation & team	5.0	2.0	2.0	2.0	2.2	2.0	2.2	2.0	2.0	2.0	3.0
Outsourcing design & engineering	5.0	3.0	3.2	3.5	3.0	3.0	4.0	4.0	4.0	4.0	4.0
Outsourcing work packages	5.0	3.0	3.2	3.5	3.5	3.5	3.5	3.2	3.6	3.5	3.5
Outsourcing functional units	5.0	2.4	2.4	2.5	2.2	2.0	2.5	2.2	2.7	2.5	3.7

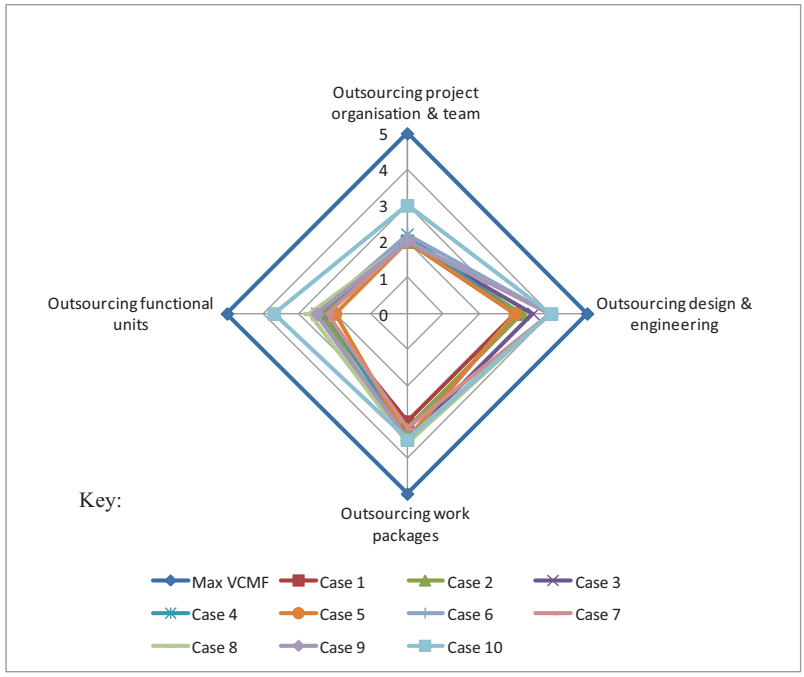

Figure 28. Range of the assessed virtuality of each of the ten case companies along the second dimension of outsourcing, by the four sub-dimensions.

5.5.3 Degrees of collaboration with the competitive network of SSCs and designers among the ten case companies (third dimension)

The third dimension measures the degree of virtuality in terms of the type of collaboration and networking relationships between a case company and its network members of designers and SSCs. The **results of the assessed virtuality** of each of the ten case companies are herein presented by these three sub-dimensions:

(3.1) Collaboration strategy with designers

(3.2) Collaboration strategy with SSCs

(3.3) Formal and informal relationships between a focal company and networked members.

In Table 16, the **assessed virtuality of collaboration with designers (3.1)** of each of the ten case companies is presented. A range of the average scores was 3.5-4.0 because (as mentioned earlier) the case companies mainly maintained long-term relationships that were based on collaboration with their networks of A/Es. Traditionally, design has been outsourced in the Finnish context. Thus, the case companies made sure that they could keep connected to those architects and engineering companies who could understand their companies' visions and project requirements.

In Table 17, the **assessed virtuality of collaboration with SSCs (3.2)** of each of the ten case companies is presented. A range of the low to average scores was 2.0-3.5 because the case companies mainly did not assume any responsibility towards their contractors and subcontractors in order to maintain long-term relationships. However, the companies were aware that they depended on trust as the key enabling factor as part of maintaining the longevity of collaboration. Cases 3, 4, and 8, with the higher average scores of 3.3-3.5, actually provided subcontractors and suppliers with training and work agreements in order to maintain steady workloads.

In Table 18, the **assessed virtuality of formal and informal collaboration with SSCs (3.2)** of each of the ten case companies is presented. A range of the average to high scores was 3.0-3.8 because the companies mainly maintained informal, collaborative relationships and preferred to arrange competitive procurement and bidding processes with contractors and subcontractors in order to get the best offers. The core competency of most companies was PM that was underpinning such

competitive arrangements coupled with more collaboration through informal relationships or less collaboration through formal relationships.

Table 16. Assessed virtuality among the ten case companies in the area of collaboration strategy with designers.

Company	Score	Description of company-specific virtuality/Sub-dimension 3.1
Max VCMF	**5.0**	A lead member connects itself to two or more A/Es in a competitive network based on their design capabilities. A/Es provide product models. It selects them based on competitive bidding or negotiations depending on projects.
Case 1	**3.5**	It had outsourced design and procured these services from among a number of A/Es with whom it had long work relationships. Selections were based on competitive bidding. Designs were procured as 2D and 3D drawings.
Case 2	**3.5**	It had outsourced design and engineering as well as procured these services from among a number of A/Es with whom it maintained long-term relationships. Selections were based on competitive bidding. Designs were procured as 2D and 3D drawings.
Case 3	**3.7**	It maintained partnering agreements with its network of A/Es in the residential development. Otherwise, it kept long-term relationships with contractors for other works. It used A/Es that could provide clients with product models.
Case 4	**3.7**	It maintained long-term relationships with its network of A/Es. Selections were based on competitive bidding so that clients made final decisions. Designs were procured as 3D drawings.
Case 5	**3.7**	It maintained long-term relationships with its A/Es. Selections were based on its recommendations to clients that made final selections based on qualifications. Designs were procured as 2D and 3D.
Case 6	**4.0**	It kept the network of competitive A/Es with whom it had long work histories and maintained long-term relationships. It recommended A/Es to clients based on qualifications and clients made final selections based on competitive bidding. A/Es provided clients with 3D designs and product models.
Case 7	**4.0**	It used its network of A/Es with whom it had maintained long-term relationships. It recommended A/Es to clients that made final selections based on competitive bidding. A/Es provided clients with 3D designs and product models.
Case 8	**4.0**	It worked with the competitive network of A/Es with whom it had long work histories. It maintained long-term relationships with those A/Es that could provide clients with product models. Selections were based on competitive bidding.
Case 9	**4.0**	It had outsourced design and today procured these services from within the network of A/Es with whom it had maintained long-term relationships. Selections were based on competitive bidding and sometimes negotiations on special projects. A/Es could provide clients with product models
Case 10	**3.5**	It maintained the network of Finnish and international A/Es. It procured design work depending on required qualifications and skills from among local or international A/Es. A/Es made 3D designs.

Table 17. Assessed virtuality among the ten case companies in the area of collaboration strategy with SSCs.

Company	Score	Description of company-specific virtuality/Sub-dimension 3.2
Max VCMF	**5.0**	A lead member assists a collaborative network of SSCs to develop their core competencies by training. It provides steady workloads under long-term collaboration. It maintained informal collaborative relations.
Case 1	**2.0**	It neither assisted its competitive network of contractors to develop their core competencies through training, nor provided them with consistent workloads as part of long-term collaboration. Collaborative relations were informal.
Case 2	**3.0**	It assisted in developing its affordable subcontractors (technically), but it did not follow a specific strategy. It did not provide consistent workloads for long-term collaboration. Collaborative relations were informal.
Case 3	**3.3**	It assumed the independence of its contractors and suppliers, but it considered that it had benefited from something new as a result of subcontractors' learning. It maintained formal relations as transactional contracts and long-term, relational contracts.
Case 4	**3.3**	It assisted its competitive network of contractors and subcontractors to develop their competencies by suggesting improvements (topics), but it did not arrange training. It did not provide them with workloads as part of long-term collaboration. Collaborative relations were informal.
Case 5	**2.5**	As a consultant, it did not arranged workloads in order to maintain long-term collaboration. It did not arrange training for developing core competencies. Collaborative relations were informal.
Case 6	**3.0**	Its core competency was PM. It did not provide parties with workloads to maintain long-term collaboration. It did not arrange training to develop core competencies. Collaborative relations were informal.
Case 7	**3.0**	As a consultant, it did not provide parties with workloads to maintain long-term collaboration. It did not arrange training for developing core competencies. Collaborative relations were informal.
Case 8	**3.5**	It assisted its competitive network of contractors to develop their core competencies by training. It provided favoured subcontractors with workloads as part of longer-term relations. It maintained special work agreements with some suppliers. It had collaboration contracts with special suppliers based on special measurable outputs.
Case 9	**2.7**	It only advised its competitive network of contractors to develop their core competencies without any training. It did not provide parties with workloads as part of longer-term collaboration. Collaborative relations were informal.
Case 10	**2.5**	Its local office in the foreign country did not assist its network partners to develop their core competencies by training. It did not provide partners with consistent workloads as part of long-term collaboration. Collaborative relations were informal.

Table 18. Assessed virtuality among the ten case companies in the area of formal and informal relationships between the case company and members in its competitive network.

Company	Score	Description of company-specific virtuality/Sub-dimension 3.3
Max VCMF	**5.0**	A lead member connects itself to two or more SSCs to supply the same systems, modules and functional elements in order to enhance competition. It nurtures trust for relationship continuity. It keeps informal relationships.
Case 1	**3.5**	It maintained the informal competitive network of contractors and subcontractors. Some of them were SSCs. The outsourcing of work was based on one-to-one and one-to-few strategies. It maintained informal relations. It developed trust for relations continuity.
Case 2	**3.3**	It kept informal, long-term relations with its network of contractors and subcontractors. Some of them were SSCs. It developed trust for relations continuity. The outsourcing of work was based on the one-to-one and one-to-few strategies.
Case 3	**3.0**	It maintained formal relations as transactions and long-term contracts with its network of contractors. It developed trust for relation continuity. It maintained the one-to-few outsourcing strategy.
Case 4	**3.5**	Its core competency was PM. It did not keep formal relations. It developed trust for relations continuity. It maintained the one-to-many outsourcing strategy.
Case 5	**3.5**	As the representative of clients, it kept informal, long-term relations with its network of contractors and subcontractors. Some of them were SSCs. It developed trust for relations continuity. The outsourcing of work was based on the one-to-one and one-to-few strategies.
Case 6	**3.3**	Its core competency was PM related to clients, designs and construction works. It developed trust for relations continuity. The outsourcing of work was based on the one-to-one and one-to-few strategies.
Case 7	**3.0**	Its core competency was PM. Its relations were formal with its competitive network of contractors. It developed trust for relations continuity. It maintained the one-to-many outsourcing strategy.
Case 8	**3.2**	Its core competency was PM. It kept special work agreements with contractors and suppliers. It developed trust for relations continuity. It maintained the one-to-few outsourcing strategy.
Case 9	**3.6**	Its core competency was PM. It did not keep contractual relations with contractors and suppliers. It developed trust for relations continuity. It maintained the one-to-few outsourcing strategy.
Case 10	**3.8**	Its core competency was PM. It kept informal yet close relations with contractors and suppliers. It developed trust for relations continuity. It maintained the one-to-few outsourcing strategy.

In Table 19, the **average**, **third dimension-specific scores** and the underlying sub-scores of each of the ten case companies along three sub-dimensions of virtuality are presented. A range of these scores along the third dimension of collaboration and networking was 3.2-3.6. The highest score of 3.6 was assessed to be with Case 8 (the general contractor). This company strived to maintain informal long-term relationships with its network members based on trust, competency enhancement and informal agreements on future workloads. The same range is illustrated in Figure 29.

Table 19. Comparison of the assessed average virtuality of the ten case companies along the third dimension of collaboration and networking, by the three sub-dimensions.

3rd dimension Networking & collaboration	Max VCMF	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Collaboration strategy with designers	5.0	3.5	3.5	3.7	3.7	3.7	4.0	4.0	4.0	4.0	3.5
Collaboration strategy with special system contractors SSCs	5.0	2.0	3.0	3.3	3.3	2.5	3.0	3.0	3.5	2.7	2.5
Formal/informal relationships with competitve network members	5.0	3.5	3.3	3.0	3.5	3.5	3.3	3.0	3.2	3.6	3.8

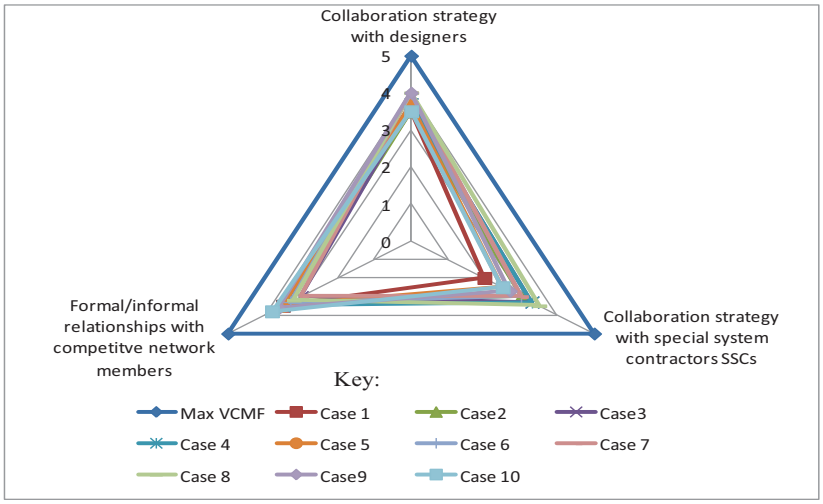

Figure 29. Range of the assessed virtuality of each of the ten case companies along the third dimension of collaboration and networking, by the three sub-dimensions.

5.5.4 Cross-case company analysis of the combined, three-dimensional virtuality

In Table 20, the **combined, three-dimensional virtuality** of each of the ten case companies is presented. However, the averages of the three dimensions of virtuality are not combined into the overall averages. Such overall averages are not valid due to the absence of a real-life best practice virtual company. Instead, the average scores of each case company along each dimension of virtuality enabled the cross-case analysis as follows. Case 9 (D-B and CM-at-risk contractor) was assessed to have the highest degree of virtuality (4.0) along the first dimension of IT-based management system. Case 10 (international division of a contractor) was assessed to have the highest degree of virtuality (3.5) along the second dimension of outsourcing. Case 8 (main contractor) was assessed to have the highest degree of virtuality (3.6) along the third dimension of collaboration with a competitive network. Overall, the ten case companies were enhancing their performance **primarily by developing their IT-based management systems** with the newly procured or self-developed software. The interviewees were also aware of collaborative relationships and their positive impacts on ensuring high performance during project development.

Table 20. Comparison of the combined, three-dimensional virtuality of the ten case companies.

Dimensions of virtiality	Max VCMF	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
IT based management sub-systems	5.0	3.1	2.8	3.3	2.9	2.7	3.2	3.2	3.6	4.0	2.6
Outsourced project organisation & functions	5.0	2.6	2.7	2.8	2.7	2.6	3.0	2.9	3.0	3.0	3.5
Collaborations & networking	5.0	3.0	3.2	3.3	3.5	3.2	3.6	3.3	3.6	3.4	3.2

In Table 21, the combined, three-dimensional virtuality is recompiled by the **two main groups of the six case contractors and the four case**

consultants. Roughly, the assessed degrees of dimension-specific virtuality were a bit higher among the case contractors (with a range of 2.6-4.0) than among the case consultants (with a range of 2.6-3.6). In the case of the first dimension of IT-based management systems, the both groups were striving to develop their IT-based (project) management systems. However, the modest difference between the two groups could mainly be due to the bigger financial possibilities of the contractors to procure newly developed software and to experiment more advanced applications of IT-based methods.

Table 21. Comparison of the combined, three-dimensional virtuality between the two main groups of the six CM-related contractors and the four CM-related consultants.

		Building construction contractors						Building construction consultants			
Dimensions of virtuality	Max VCMF	Case 1	Case 2	Case 3	Case 8	Case 9	Case 10	Case 4	Case 5	Case 6	Case 7
IT based management sub-systems	5.0	3.1	2.8	3.3	3.6	4.0	2.6	2.9	2.7	3.2	3.2
Outsourced project organisation & functions	5.0	2.6	2.7	2.8	3.0	3.0	3.5	2.7	2.6	3.0	2.9
Collaborations & networking	5.0	3.0	3.2	3.3	3.6	3.4	3.5	3.3	3.2	3.6	3.3

In Figure 30, the same range of the assessed, average three-dimensional virtuality is illustrated as a reflection of the case companies' real life. It is evident that the ten case companies (except Case 10) were less virtualised along the second dimension of outsourcing compared with the other two dimensions. The companies did not plan any big increases in virtuality in this area, not to mention a full outsourcing of project organisations and functional units. Most interviewees perceived that effective CM/PM, WBS preparation, design management, cost estimating, and permanent in-house key staff were among those **core elements** that guaranteed their competitiveness in the market. When these company-specific and dimension-specific scores are **compared** to those of the max VCMF (with its scores of 5.0), it is obvious that all of the case companies are swimming in a cloud of virtuality with the degrees that are far from the highest level of the max VCMF. Yet it will be interesting to watch which of the two groups (the contractors or the consultants) will lead the way towards achieving higher virtual performance in the coming years.

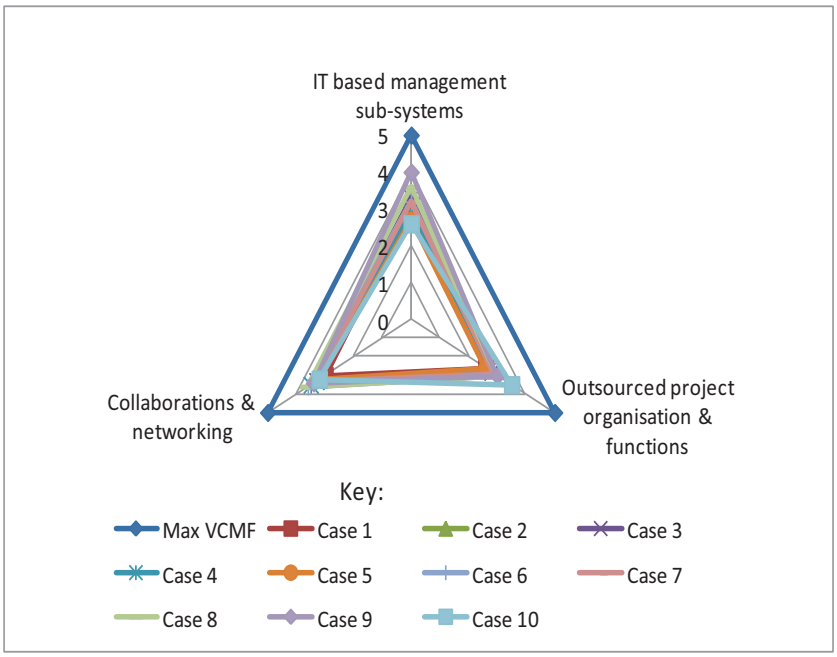

Figure 30. Range of the combined, three-dimensional virtuality of each of the ten case companies, by the three dimensions.

6. DISCUSSION

In this chapter, the model design task is discussed in terms of the applicability of the selected theoretical bases and the validity of the virtuality model and the max VCMF model as the two theoretical constructs. Thereafter, the applicability of the virtuality model for the benchmarking process in terms of the max VCMF model as a measurement tool is dealt with. Finally, the conclusions and the suggestions are put forth as the contributions and boundaries of the study, the recommendations to practitioners, the future applications in the real world and the implications to researchers.

6.1 Generic and applied modelling approaches and their applicability for designing the two construction-related models

For this study, the triggering questions were "Why does the construction industry need virtualisation?" or "Why should construction companies adapt themselves to performing virtually?" In general, the construction industry is known to be highly fragmented, as a typical construction project usually involves an ad hoc team of different firms dealing with certain aspects of the project and is often only interested in improving their own productivity. Also, the global construction industry is facing fundamental changes which require construction organisations to radically review what products and services they provide and how to provide them in a more competitive way (Kiiras et al 2002). On the other hand, construction companies usually do not go into radical changes in their organisational structure and/or performance unless they are in crisis, an example of this is the focal Finnish construction industry, as the establishment of CM consultants and CM-at-risk contractors was triggered by the recession in the early 1990s. It is only then that traditional building contractors considered changing or complementing their strategies and principles of organising themselves by considering new ways of streamlining, in particular by adopting a vision that can be characterised as becoming virtual contractors. By the early 2000s, pioneering firms had started to

strategically renew themselves based on the availability of advanced IT infrastructure and ICT development (Kiiras et al. 2002, Kiiras & Huovinen 2004).

The generic modelling approaches and their applicability for the design of the two contextual models are discussed herein in terms of the trends, characteristics and the four primary dimensions in solving the contextual virtualisation problem. At the outset of this study, it was acknowledged that virtualisation is the underlying trend. In the pre-reviewed, general literature on virtuality, there are many distinct efforts to conceptualise VOs at the firm level, such as Goranson's (1999) agile virtual enterprise, Camarinha-Matos & Afsarmanesh's (2004) collaborative network organisation, Camarinha-Matos & Afsarmanesh's (2003, 2005) tools of VOs and systems as well as Davidow & Malone's (1992) virtual corporation. Further, virtualisation is seen as a set of strategic characteristics involved in the delivery of superior value to clients, i.e. to consistently obtain and coordinate critical competencies, design value-adding business processes and exploit powerful, integrated IT platforms, aligning with Venkatraman & Henderson (1998). In this respect, Saabeel et al. (2002) and Christiansson (2001) state that VOs flexibly adapt themselves to changing business environments by reconfiguring organisational structures with new competencies. In turn, Coulson & Kantamneni (2003) state that VOs exploit potential windows of opportunity where it is difficult if not impossible for individual members to exploit such opportunities alone.

For the model design task, it was recognised early on that the dimensions and principles of core competencies, outsourcing, ICT systems and networking could be adopted to solve the virtualisation problem in the focal context of construction. (i) Core competency strategies underlie the understanding of virtual organising strategies, aligning with Barnatt 1996 and Camarinha-Matos et al. 2005, i.e. firms concentrate on what they do best, specialise in certain areas and link themselves with value chains where they can reconfigure their own core competencies with those of other members for optimum value creation. At the same time, it was understood that the emergence of VCs was linked with (ii) extensive outsourcing strategies. Outsourcing is being triggered by needs to assure customers with high-quality performance and consecutive strategic choices such as focusing on core functions, acquiring new skills, reducing costs, engineering fixed costs into variable costs, avoiding major investments and enhancing credibility (Baden-Fuller et al. 2000, Bragg 2006). (iii) In turn, ICT strategies were perceived as being the necessary enabler to virtual

performance. The telecommunications infrastructure including the Internet has boosted productivity as part of developing competitiveness in global markets, anticipating the emerging information society and distributing software electronically via the Internet (Maier & Traxler 1995). However, it was also realised that the engagement of remote individuals to computer-supported, collaborative work does not necessarily mean a move towards running a true VC. Instead, it seems that virtual organisational forms require changes in relationships between organisations and their human resources (Barnatt 1996).

In particular, (iv) it was assumed that an applicable model of virtual firms can be designed so that one of the key dimensions involves networking as the organisational form of the information age (de Man 2004). Thus, VCs are seen as entities that resemble temporary, dynamic and loosely-coupled networks consisting of legally independent members that combine and optimise their individual core competencies to exploit specific business opportunities and create superior value (Bauer & Köszegi 2003, Saabeel et al. 2002). Generic VCs as networks are modelled along the five structural dimensions that include the core differentiation based on core competencies, the configuration of respective, overall structures and networks to meet changing customer requirements and the soft integration (mechanisms) of modularised production throughout value-adding processes (Bauer & Köszegi 2003) as well as the virtual, coordinated realisation of modularised processes enabled by ICT (Venkatraman & Henderson 1998) and the collaborative, organisational and human relationships that facilitate exchange between members who are likely to sacrifice some of their own preferences for collective goals and knowledge creation (Fleisch & Österle 2000, Franke 2001, Camarinha-Matos & Afsarmanesh 2004).

For the model design task, the generic modelling approaches were selected during the period 2006-2007. It is argued that by relying on both the core competence strategy and the collaborative networking, it is possible for CM firms to sustain their virtual networks as long as a lead firm and members can add value. In turn, when coupled with the extensive outsourcing strategy, it is possible to reconfigure critical capabilities through different relationships within business networks. Similarly, the incorporation of IT systems enables the virtual management of modularised building production, as virtuality is happening in other industries (Balint et al. 1998). This is being realised through a large number of applied programmes for construction contexts (Sun & Howard 2004).

Besides, more recent generic publications on virtualisation have been followed up during the preceding years of 2006-2010. Overall, no recent references were selected for use as part of the model design task. It could be recognised that the general literature on virtuality has been evolving around almost the same early notions and models (e.g. Holm 2007). This choice can be supported with Groznik et al.'s (2011) extensive review of the published, generic VO models. Therein, Travica's (1999) ISSAAC model of a VO, Mowshowitz's (1999, 2003) tool as the switching principle, Meister's (2000) TEMPLET model, Scholz's (2000) virtual cube, Bavec's (2002) model with a radar chart, and Migliarese and Ferioli's (2005) organisational relational model are considered to be the primary contributions. Groznik et al. conclude that all these models can be used to assess organisational virtuality for various purposes and each of them could be advanced further. They also present their new model called the Growth Pillars of the VO, where they have included many of the best features of the reviewed models along the two groups of dimensions (operations, organisations) coupled with the six respective attributes (technology and knowledge, processes, participation; dispersion, flexibility, information). The intersections of those attributes constitute the nine elements of the model. The model is empirically tested and, according to Groznik et al., it proved to yield the valid results. It is a clear visual representation that is practical and suitable for real-life research therein that it contains the necessary elements to deliver repeatable results. From this researcher's point of view, Groznik et al.'s (2011) newly developed growth model supports the researcher's idea that virtualisation should be considered, developed and managed at the firm level and the project level concurrently. The three-dimensional virtuality model designed in this study captures the contextual virtual phenomenon to a reasonable extent for the time being. Had Groznik et al.'s model been available at this study's outset, it might have guided the benchmarking towards a more qualitative process.

Concerning applied modelling approaches vis-a-vis construction contexts, no valid model or application, for the model design task, could be identified during the literature review. So far, no construction-related scholars have been interested in conceptualising a virtual construction company as a whole entity, i.e. virtualisation at the firm level. Similarly, no applied concepts have been found concerning virtualised management systems either at the firm level or the project level. Instead, it seems that the focus is on virtualisation at a project level, i.e. advancing virtual project practices (e.g. Owen et al. 2010).

6.2 Validity of the three-dimensional virtuality model and the max VCMF model

The model design task involved the adoption of the dimensions and models of the virtuality notion and their key characteristics from within generic references as well as the application and combining of the selected, generic pieces with the applied, theoretical and contextual knowledge on construction companies. This was coupled with the empirical knowledge on the behaviour and states of such companies in the focal context of the Finnish construction industry. All this resulted in the **two models,** i.e. the three-dimensional virtuality model and the max VCMF model. The latter is embedded in the former as its operational mode. The validity discussion addresses herein each of the models as an applied, theoretical construct or a causal-descriptive, white-box model within system dynamics. However, there are no established formal tests that one can use in deciding if the structure of a given model is close enough to the "real" structure (Barlas 1996). Thus, the **validity of the internal structures** of the two models is discussed in terms of how adequately these respective structures represent those aspects of virtuality and virtual CM firms in the envisioned, focal context of the Finnish construction markets that are relevant to their competitive behaviour and business performance in the future.

6.2.1 Validity of the three-dimensional model as an applied, theoretical model

It seems that it is highly likely that the three-dimensional virtuality model is **pioneering** in terms of choosing and specifying each of the three dimensions so that they accommodate the virtualisation of CM firms as whole entities. In principle, virtuality as a strategic characteristic is applicable to construction companies, too. Each firm can plan and achieve its pursued level of virtualness along relevant dimensions that cover the key aspects of its organisational structure and performance (aligning with Venkatraman & Henderson 1998, Scholz 1998a-b). By the mid-2000s, the focus of the theoretical and empirical research on construction across various national contexts was on virtualisation and re-engineering at a project level, i.e. no applied model related to firm level management was readily available. Thus, Scholz's (1998a-b, 2000) virtual cube, with its structural and process perspectives, was adopted in order to capture the firm and project levels via the virtuality model design. The preliminary investigation of the Finnish (traditional and new) case companies revealed

that they differed in their degrees of virtuality and that their virtual PM performance could not be fully captured along a single dimension of an IT-based management system. In addition, the case companies virtually exhibited both structural and organisational aspects that resulted in the assessment of the outsourcing of functional units and project work as well as the level of collaboration between the case companies and their networked and contracted companies. Thus, the IT-based PM and CM perspective, together with the outsourcing and collaborative network management perspectives, turned out to be highly relevant when designing the three-dimensional model of virtuality. Admittedly, each dimension accommodates only the virtualisation of a particular aspect of a firm's performance. However, the three dimensions are so deeply intertwined that collectively they enable virtualisation at the firm level and the project level. This implies that Finnish CM firms can use the three-dimensional model as a frame of reference when they start to plan and pursue their higher degrees of virtuality. For the three-dimensional virtuality model design, the three kinds of the theoretical bases were adopted from among the relevant literature, i.e. the generic theoretical bases on virtuality, the selected virtual practices in other industries, and the traditional practices as well as the virtual practices and their development in managing building projects in the focal context. Thus, the three-dimensional model is also valid to a varying extent in other business contexts.

Along the **first dimension of IT-based, collaborative management systems,** CM firms can virtualise themselves by managing dynamic and rapid changes, creating and deploying intellectual and knowledge assets as well as sourcing tangible and physical assets from within their complex networks of relationships. The scope of virtual managing encompasses project work, client relationships and competitive network members. All this can be supported by integrated IT platforms.

Along the **second dimension of outsourcing,** traditional construction companies have already been outsourcing project development and building design, the supply of building products and construction materials as well as construction works. In turn, CM firms, in an attempt to differentiate themselves, have extended their outsourcing strategies and are thus typically procuring project WBSs and BoQs from specialised consultants as well as preparing large work packages and inviting SSCs to benefit from these and incorporate their know-how through the detailed design of their system packages. Therefore, the outsourcing strategy as one key dimension for virtualisation is capturing all such transformations

among focal firms in Finland. The outsourcing accommodates high flexibility and agility so that more virtualised CM firms can swiftly configure partial networks every time a new opportunity for a project arises.

Along the third dimension of competitive networking, CM firms can aim at organising virtually and contracting effectively for project-specific capabilities through a network of designers, suppliers and subcontractors. They can also ensure the availability of critical competencies through the repetitive configuration within their networks and among their relationships. In turn, designers, suppliers and subcontractors can engage themselves with memberships in many networks in order to differentiate, and concentrate on core competencies. In the case of Finland, special system contracting has been developed as a first move towards competitive networking in order to advance the adoption of extended building contracts (Salmikivi 2005).

6.2.2 Validity of the max VCMF model as an applied, theoretical construct

A **vision** behind the design of the max VCMF model includes a radical, transformative path towards a flat organisation, along which a CM firm relies on the extensive outsourcing of functional units and project work, the development of core competencies and the reconfiguration of critical capabilities via its competitive network of designers, staff pool and SSCs. Future, higher virtualisation among CM firms is initially explained as reactions to increasing competitive pressures. It is herein argued that **isolated moves** along one of the three dimensions are not adequate for achieving highly effective performance in correspondence to that of the max VCMF model.

While traditional construction PM systems are herein considered incomplete, CM firms are encouraged to upgrade their current management systems to an **IT-based management system** where processes for managing project work and networked relationships are being integrated (along the first dimension). In the context of Finland, leading CM firms have already upgraded their management systems to IT-based, integrated management systems for more traditional reasons, i.e. to improve their productivity, etc. However, there are no definite signs that would indicate moves towards extensive outsourcing and competitive networking.

While existential functions such as ownership, strategic management and bidding are kept internalised, CM firms can phase and realise **strategies to extensively outsource** functional units such as design, engineering, cost estimation, financing, administration, site management, site engineering, project teams and work so that the maximum flatness of a VCMF can be achieved (along the second dimension).

Naturally, the outsourcing implies that CM firms create and manage **their collaborative and competitive networks** of members like SSCs in order to provide clients with modularised systems and services, respectively (the third dimension). A particular (lead) firm can select and use both the formal and informal forms of collaboration with SSCs, designers and staff pools in order to achieve the targeted, consecutive degrees of virtuality. Indeed, leading firms can combine SSCs as independent core competencies in order to produce an optimised value chain under each CM contract.

CM firms can develop and exploit **integrated systems for effective network, project and information management** between internal and external stakeholders on their path towards the max VCMF and its competitive network. Moreover, firms can integrate the seven subsystems with the help of an **advanced, three-part BCIM.** Therein, firms can exploit the latest, existing BCIMs and supporting libraries (e.g. Firat et al. 2006, 2008a-c, Arditi 2007) as databases and Internet-based solutions for creating products, managing resources and costs, designing process models, integrating network and PM subsystems as well as involving networked SSCs early during detailed design phases. In the case of Finland, such commercial software and related training services are already available on the market.

The management of CM firms can aim at and attain higher degrees of virtuality through the five effective business processes (client relationships, sales and bidding, product design, procurement, construction and handing-over as well as after-sales services). In turn, the IT-based seven subsystems of the network and PM are herein considered adequate to provide virtualising CM firms with enabling management services. An IIS enables virtual knowledge management, i.e. SSCs become a source of expert knowledge and offer competitive sub-solutions for those offerings with which CM firms compete in (inter)national arenas. The latter can also acquire information for partner searches through directories that contain information about preferred, profiled firms (e.g. Alsakini et al. 2008a-c).

The max VCMF model with its enabling IIS integrates the seven management subsystems in an innovative way, as an applied, theoretical construct. In particular, each of the seven management subsystems **advances the virtualisation of CM firms in the respective focal areas** as follows:

(1) **Project Owner Relationship Management System (PORMS)** enhances the quality of a CM firm's services through the pre-emptive building of expert relationships. An IIS facilitates a PORMS' performance by providing real-time information for managing relations with owners (as root clients) better and better. This coupling of CRM and CPM is a fairly novel area as part of integrated management systems.

(2) **Project Offering and Bidding Management System (POBMS)** enables the virtualisation of both business processes and project processes. An IIS provides a lead member with information required for deciding upon a WBS and bid packages across a series of projects. The internal competitive tendering is a means to exploit and integrate the system-specific know-how of each of networked SSCs.

(3) **Project Design and Engineering Management System (PDEMS)** enables the establishment of a building product model that, in turn, allows real-time access to most recent design documents. A building-specific product model is provided by a collaborative design firm. Each SSC designs its system virtually and contributes early enough to the detailed design of a system or a project package. An IIS links engineering analyses and design solutions so that a design process results in a complete building product model that combines architectural and engineering simulation models to speed up calculation processes and building simulations as well as to predict the life cycle performance of buildings and systems. Detailed engineering is carried out by SSCs based on their know-how and expertise.

(4) **Networked Project Procurement Management System (NPPMS)** enables the leveraging of competitiveness in terms of integrating sub-offerings and procuring a set of special systems (of buildings) across a series of projects. An IIS provides real-time procurement information. During each bidding process, a lead member selects from within an internal list some SSCs whose work histories and profiles match those special systems, expert processes

and services that fall within the scope of a targeted project. A lead member sends bid packages via the Internet to selected SSCs for their sub-bid preparations.

(5) **Construction Planning, Execution and Control Management System (CPECMS)** enables virtual CPM with an advanced core, i.e. a master plan and a set of activity plans/schedules with rolling windows, across a series of projects. An IIS provides information for procurement, construction tasks and site activities with their interdependencies, durations and costs. For control, each SSC prepares its detailed activity plan/schedule and integrates it into a real-time master schedule. Design changes are fed into a process model so that up-to-date execution plans and schedules are available on an ongoing basis. Cost information is fed into a process model based on actual expenditures among SSCs and other subcontractors on respective sites.

(6) **Commissioning and After-Sales Services Management System (CASSMS)** enables the virtual life cycle management of respective focal buildings. An IIS uses information that is being collectively generated through the other six management subsystems and the information systems. The VCMF hands over an updated building life cycle model to each owner (client) for a basis of managing and acquiring life cycle services.

(7) **Network Nurturing Management System (NNMS)** enables a lead member to develop the competencies of its network in order to produce more innovative building solutions in a series of future projects. An IIS provides a lead member with information for new partner searches. This coupling of network nurturing and CPM is a fairly novel area as part of integrated management systems.

CM firms can establish and/or upgrade their five PM subsystems within the well-known, corresponding areas of PM (e.g. PMBOK 2003) and CM (e.g. Kiiras et al. 2002). In addition, firms can plan their CRM systems and network management subsystems along the advanced thinking and solutions in this area (Pinto & Rouhiainen 2001, Hoover Jr. et al. 2001, Gadde & Håkansson 2002, de Man 2004).

In part, CM firms can follow up and benchmark R&D programmes with their project level targets within the EU and elsewhere in order to exploit the latest applicable solutions. Some proven examples include EU DIVERCITY 1998-2002 for distributed virtual construction workspace (Christiansson et al. 2001, Fernando et al. 2001), VIRCON for developing a

methodology and decision support system for the evaluation, virtualisation and optimisation of construction schedules (Dawood et al. 2001, 2002) and LEWIS for re-engineering workforce information (Sriprasert & Dawood 2001) as well as the compatibility of project teams and tools (Fernando et al. 2001, Arditi & Balci 2009, Becerik 2005), the role of IT in construction (Betts 1999, Sun & Howard 2004) and advanced construction sites (Kazi 2005, Kazi & Wolf 2006).

6.3 Applicability of the max VCMF model as a measurement tool

It should be restated that today there are no CM firms in the real construction world that would comply with the characteristics of the fully virtual CM firm. Due to this non-existence, it was necessary to investigate the applicability of the three-dimensional model of virtuality in another scientific way, i.e. in terms of the applicability of the max VCMF model, which exhibits the highest characteristics along the three dimensions of virtuality, as a **tool for measuring and comparing the various degrees of real virtuality** among CM firms and construction companies. While no valid guidelines could be found from within the methodological literature, many principles of **performance measurement** could be applied to ensure the rigorous conduct of this benchmarking process. Namely, CM firms can also communicate their business goal-setting and goal-achievement through performance measures (what to measure) and measurement tools (how to measure) both internally and externally (aligning with Alarcón et al. 2001). Each choice of specific performance measures for showing relevant variations and improvements depends on the specific characteristics of the unit of measurement (Kagioglou et al. 2001).

In turn, the applicability of the max VCMF as a measurement tool is herein addressed in terms of the critique of the maximum and the constructive easy-to-use criterion. For the benchmarking process, the max VCMF model was adapted to serve as a tool for measuring the DV of each case company. The max VCMF exhibits the preferred characteristics within the three-dimensional virtuality. The adapted scope of each dimension and its sub-dimensions could grasp the specific issues that were desired to be measured. (i) Some pragmatic critics can rightfully question the max VCMF model as an overly radical model of excellent performance. It is herein posited that the maximum level of the model is realistic to the extent that the reviewed and adopted characteristics from within the literature together

define the maximum model (Bauer & Köszegi 2003, Scholz 1998a-b and 2000, Kiiras & Huovinen 2004).

At the same time, the adapted VCMF model as a measurement tool must meet the key criterion of constructive research, i.e. (ii) the **measurement tool is simple, relevant and easy to use** (Kasanen et al. 1993). In this study, the tool was specified so that the assessed degrees of virtuality within each case company could be related to the **necessary, causally-related conditions** of targeted high performance in the future. The business goals and strategy of the max VCMF cannot be achieved and the lead member cannot manage its networked processes and members without the advanced IS/IT strategy. In turn, the IST/IT strategy is needed for guiding the use of the Internet, commercial software, seamless integration, cost minimisation, IS operability and IT training. The seven subsystems enable the integrated management of project owner (client) relations (PORMS), network nurturing (NNMS) and projects (via POBMS, PDEMS, NPPMS, CPECMS and CASSMS). The seven subsystems are integrated via the three-part BCIM consisting of the building product model, the resource and cost model and the process model. Moreover, the delivery system of the max VCMF is based on the extensive outsourcing of the lead member and the competitive networking with SSCs. Thus, the procurement and PM processes are needed to ensure product flexibility, design change flexibility, short delivery times and the concurrency of design, procurement and construction works on site. Network members should add value-for-client money through their product expertise, whereas a lead member focuses on enhancing its CM and PM expertise.

At the beginning of each interview, the interviewer described and explained the max VCMF model and the embedded causalities to the interviewee so that he or she could comprehend the coverage and the causalities along each of the three dimensions. Along the **first dimension** of the IT-based integrated management system, the existence and non-existence of network-related management subsystems could be measured besides the usual PM system, the extent of using the IT systems to support each subsystem was detected and the varying reliance on using the building information models to enable the integration of management subsystems was also revealed. Along the **second dimension** of outsourcing, the degrees of the outsourcing (and procurement) of project organisations and teams, design and engineering services, project work packages and functional units could be investigated. Along the **third dimension** of competitive networking, the extent of the collaboration with the designers,

the SSCs, the subcontractors and the suppliers could be specified as well as the formality or informality of the relationships and the role of trust could be assessed.

6.4 Accuracy of the interview-based collected data

The researcher/interviewer maintained the accuracy of the collected data by involving the interviewees inside the ten case companies with the self-assessment of the degrees of virtuality, respectively, as follows.

(i) **The theme interviews with the semi-structured questionnaires** were carried out as the face-to-face dialogues and the discussions with the selected interviewees in their respective managerial positions within the case companies (see Appendix 1). The data gathered through the interviews concerns the interviewees' views upon how work is being conducted within and by case companies corresponding to the three-dimensional scope of virtuality. The consistency of the data was ensured by including the same six case companies in the preliminary and thematic interviewing rounds. A time lapse of two years between the two rounds with the six case companies enabled the detection of any changes in the companies' management functions and their degrees of virtuality. Interestingly, only one major change could be traced, i.e. a strategy change involved the temporary giving up of the adoption of BCIMs in PM due to the unsuccessful application in a pilot project, which resulted in the project delay and the cost overrun (Case 2). In the same vein, the researcher included the additional four case companies in the theme interviews and this enlarged the interview data and increased the reliability of results. The interviews were recorded and transcribed. The interview data was used to validate the data collected via the self-assessment questionnaires that the interviewees filled in and sent to the interviewer. Nevertheless, the interview processes were limited by the time constraints and hindered by a fact that virtuality as a topic was not well understood by these practitioners.

(ii) The **self-assessment questionnaires** were used in order to gather the interviewees' quantitative self-measurements of the degrees of virtuality of their case companies (see Appendix 2). Each interviewee compared their own company's performance against the max VCMF's performance with the help of the detailed statements on a scale of 1 (very low)….5 (very high). Some interviewees were late in submitting their self-assessments, which was understandable due to their busy schedules. In order to ensure the

accuracy of the self-assessment data, the interviewer compared the interviewees' scores with her own scores, respectively, so as in the case of a discrepancy the interviewer could report on this back to the interviewees for their confirmation and/or correction. In this way, the interviewer could double-check the interviewees' perceptions from the two angles, i.e. (i) how each interviewee elaborated on her/his company's own performance against the three dimensions of virtuality during the theme interviews, and (ii) how each interviewee compared and assessed her/his company's performance against the max VCMF's performance via the self-assessments.

(iii) The **case companies** were selected from among the leading companies in the building market in Finland. The overall number of the case companies did not need to be large, i.e. a low number of the participants was not seen as an obstacle for the study as there was no primary intention to generalise findings. The ten case companies served well to develop the interviewer's understanding about virtuality as a new phenomenon in the focal context. They represented both the CM consulting and the CM (and general) contracting. It was essential to include a mix of the traditional companies and the entrants in order to detect the variant degrees of virtuality. The case companies varied in size between large and medium. The five case companies operated only inside Finland while the other five case companies also had the extensive operations in the targeted international markets.

(iv) The **interviewees** were selected from among the top management of the ten case companies in order to assure the accuracy of the collected data. Each interviewee had her or his first-hand knowledge of this case company's strategies and management practices. As the key decision-maker, each interviewee could decide to what extent he or she could give their company's internal information to the interviewer during the interviews so that the reliable picture could be drawn from the interview data. Beforehand, each interviewee was promised the anonymity of the case company and the confidentiality of the provided information. In this way, the interviewees were willing to discuss the issues related to the perceived virtuality more openly. The interviewer explained in sufficient detail the three-dimensional virtuality model and the max VCMF model to each interviewee, accompanied with the illustrative printed slides, so that he or she could comprehend what was going to be discussed during the interview as virtuality in general was not well understood among the practitioners. The interviewer met no clear limitations in this respect as the interviewees

were fully supportive during the interview sessions. Similarly, the interviewer did not identify any planned limitations within the self-assessments and the scores that interviewees submitted after the interviews.

6.5 Conclusions and suggestions

6.5.1 Contributions to the theoretical knowledge on virtualisation and CM firms

It is herein posited that this study contributes to the existing, generic and applied theoretical knowledge as follows. (i) The **three-dimensional virtuality model** has **some novel generic features** in terms of how the three dimensions are combined in order to complement each other to achieve the virtual performance of a CM firm at both the firm level and the project level. Admittedly, many pioneering firms can today achieve their virtual PM performance and enhance their productivity with the help of IT–based management systems. However, these firms do not (yet) constitute true virtual entities, mainly because performing virtually at the firm level requires changes in each firm's organisational structure. In turn, this can only be achieved by changing an outsourcing strategy, collaborating with networked members and developing a system to manage such a new network besides the core PM systems. The three dimensions of virtuality are not novel on their own. Even when there is a clear absence of any intention to become virtual, a particular firm can plan and achieve a certain level of virtual performance along one dimension in order to capture certain efficiencies and productivity.

In turn, (ii) the max VCMF is a **novel piece of applied, theoretical knowledge** that captures the essential characteristics and dynamics of CM firms across national contexts of (inter)national building markets. For the max VCMF, the network system is new, as novelty is inherent in a principle way in how the skills and expert knowledge of networked SSCs are being exploited and pulled together to make detailed engineering and activity planning solutions realistic, economic and highly controllable (aligning with Gotfredson et al. 2005, Baden-Fuller et al. 2000). It has been accepted that the management of virtual entities differs significantly from the management of traditionally organised firms. In turn, ICT-based solutions and applications are considered the key enablers (and disablers) for the management of such virtual players. Novelty is also inherent in the way BIM modelling is used in order to enable the integration of both network

and project management subsystems and to manage information generated during project development phases, so that all this provides virtualising firms with more efficient production and clients with higher value. This is coupled with the comprehensive virtual model of a building, its realisation process and interactive users. Such BCIMs are based on the commercial software that allows the semi-automatic, partly interactive generation and production of information (aligning with Firat et al. 2006, Eastman et al. 2008).

As none of today's CM firms in the building industry complies with the characteristics of a fully virtual firm, the adapted VCMF model serves as **a frame of reference and a tool for assessing the degrees of virtuality** of any CM firm within the three-dimensional scope of virtuality as well as for planning a future virtualisation strategy. The tool helps to evaluate alternative strategic directions and choices along any or all of the three dimensions, in order to proceed towards the desired types and degrees of virtualisation. The maximum model exhibits the viable characteristics of a virtual CM firm. These structural and process characteristics are the highest reference values along the 14 sub-dimensions that can be incorporated into any future comparisons with the real, current characteristics of those CM firms that become interested in measuring their degrees of virtuality.

The **usefulness** of the VCMF model as the tool is related to each of the three dimensions. The first-dimensional virtualisation of a traditional management system towards an IT-based collaborative management system may vary. A particular lead member makes its decisions based on an IT strategy, the availability of ICT-based systems vis-á-vis pioneering them itself, the software integration to assure data compatibility as well as Internet-based solutions and training needs. Second dimensional moves depend on a lead member's decision upon what functions to outsource versus keep in-house and what core competencies are kept in-house versus accessed via a competitive network of SSCs. In turn, the third dimensional, competitive networking depends on the availability of new SSCs, foreseen trust-based relations and the effective use of ICT applications among network members to allow for a faster virtualisation process.

In the case of **CM firms in the focal context of the building market in Finland,** the comparison of the case companies and their management systems against the max VCMF's management system produced many **insights into what elements these ten companies could develop**

next, when they decide on heading towards higher degrees of virtuality in the future as follows: (i) The existing subsystems are more like tools when compared with managing relationships with clients and network members. Thus, the interested case companies can invest in developing such management subsystems at the firm level in order to grasp the most attractive project opportunities and to network with the best service providers. (ii) The incorporation of the BCIM into the case companies' traditional management system requires the significant development efforts as well. Besides product, resource and cost models, supporting libraries are also needed for getting BCIMs as a whole into real productive use.

It seems that the VCMF model as the tool is useful for both entrants and traditional construction firms in improving the planning and development of their virtualisation. In terms of entrants, a strategy of virtualisation can be planned at the outset concerning the types and degrees of virtuality that are required and the dimension(s) along which virtualisation is pursued. In the case of traditional firms, it is possible to apply the operational mode of the max VCMF model on a project basis by developing a virtual organisation simply to execute a particular project, while there is no need to fully restructure the firm itself. It seems that the three-dimensional model of virtuality and the max VCMF model are valid in CM services businesses across contexts inside (inter)national building markets, i.e. the three dimensions and the principles of managing and diagnosing virtualisation capture phenomenal issues while local features as part of focal contexts are taken into account in applications.

6.5.2 Boundaries of this constructive study

This doctoral dissertation is based on the **five-year research process** during the period of 2006-2011 in which the author worked as the full-time researcher. Consequently, this monograph has been preceded by the individual studies that were peer-reviewed and evaluated individually for the presentation in the respective academic forums. The study has also been reshaped and revised following the valuable feedback before the actual publishing. For this study, the **constructive research approach** (Kasanen et al. 1993, Lukka 2000) was adopted and applied with the certain limitations as follows. Both the relevant contextual problem and the theoretical phenomenal problem related to virtuality could be defined as the required starting points. Thus, the virtualisation of CM firms was approached and enabled by **designing the two constructs or models**

based on the selected, generic and applied theoretical references on virtuality and the virtual practices in other industries as well as the contextual references on the traditional and virtual practices and the developments in managing building projects.

In principle, Gummesson (2000) argues that **challenges in management research** include a researcher's pre-understanding (knowledge, insights) and understanding, access to reality and the quality of a study. This researcher acquired her basic knowledge about contextual problems through the reviewing of the relevant literature and the findings during the prior study in the early 2000s within the Laboratory of Construction Economics and Management at the Helsinki University of Technology (now the Aalto University School of Engineering). The researcher built her **pre-understanding** for this study as the progressive process of moving back and forth between the theoretical sphere and the empirical sphere. Therein, the model design, the collection of the empirical data, the data processing and analysis as well as the writing of the scientific papers evolved simultaneously. The final phase was this doctoral dissertation, which links all the prior activities and their outcomes into one entity and gives the overview of the whole research process.

On the one hand, the **thorough review and investigation of the generic literature on virtuality** was necessary so that the researcher could familiarise herself with the roots of the research problem, find out what has been achieved in this respect as the proven and verified solutions and learn some insights that could be used to develop and synthesise a novel solution of her own. The abundant literature on virtuality and generic VOs was reviewed in order to learn about the evolving phenomenon without limiting contexts. In addition, the deeper and complementary follow-up of the recent literature was necessary in order to identify those concepts that would be relied upon when the two own models were designed, their validity was criticised and the applicability of the virtuality model in terms of the max VCMF model as the measurement tool was investigated and these findings were related to the existing bodies of knowledge. Later, the researcher deepened her understanding via participating in the Found IT Project (for taking e-collaboration techniques into productive use in the construction industry) within the KITARA programme activities of the KIRSU Doctoral School at the Helsinki University of Technology.

On the other hand, the understanding and solving of the contextual research problem required the **review of the relevant literature on the construction contexts**. While there is the vast literature on construction PM and CM, the literature on virtuality in the focal contexts of building markets is almost solely focused on advancing the virtualisation of project teams and tools, workplaces and project sites as well as the role of IT in construction. It was disappointing to realise that no literature had been published on the virtualisation of construction firms as whole entities by the mid-2000s. This has been a major limitation of this study, i.e. the **lack of the literature on virtualisation in the context of construction or project-based industries.** No prior references could be relied upon when the firm level and the implications of virtualisation on a firm's management functions were approached. In part, this limitation could be compensated for by focusing on and applying the literature on virtuality and generic VOs as well as some applied frameworks with other industrial contexts.

Contextually, the researcher visited the case companies based in Finland during the two rounds of the interviewing and the benchmarking process. Thus, the researcher gained the **sufficient practical understanding** of the degrees of virtuality in this focal context. Understandably, the researcher has been lacking the detailed knowledge of daily practical operations due to her role as a full-time researcher.

In turn, the **lack of empirical evidence** prevented the researcher from substantiating a possible number and types of the dimensions of virtuality and the applicability of each dimension to virtualise and measure the levels of virtuality in CM firms. Indeed, before this thesis any attempt at a meaningful empirical study in this area would have been without a directed focus or scope. Future researchers can use this thesis as a basis for their empirical investigations of the same and other dimensions of virtuality as well as their applicability under the given requirements. Also, as it is not known yet how much virtualisation is appropriate for what type of a contract, what type of a construction project, and what type of culture, etc., optimum levels in virtualisation need to be studied.

Time-wise, it was impossible to think about that it would have been advantageous for the empirical results of this study that the case companies could be interviewed for the second round for some time after the first round of the theme interviews, in order to substantiate the first findings and evaluate how far the case companies would have developed along the

three dimensions mainly because progress and changes along these dimensions is a lengthy process.

An additional limitation of this study is inherent in a fact that this researcher had **no realistic possibility to broadly cover the literature on some key issues related to the two models** such as (i) contemporary ICT, (ii) ICT system configurations and (iii) ICT solutions. Nevertheless, the three-dimensional virtuality model and the max VCMF model could be designed as the two fairly novel models without the sub-design of any in-depth ICT applications.

6.5.3 Interview-based findings and recommendations for CM firms

Recommendations for CM firms are put forth dimension by dimension as follows. The **first dimension of virtuality** accommodates the IT-based, integrated project and network management system. Becoming virtual is more than just using IT as a necessary enabler and promoting oneself as a highly virtual CM firm. The empirical findings showed that the average scores of the case companies varied 2.6-4.0 mainly because all the contractors were upgrading their traditional PM systems and processes into the IT-based ones in order to increase their efficiency and productivity. Also, the CM contractors were more eager to use IT in PM systems than the CM consultants did, with the average scores ranging 2.7-3.2. It is likely that the CM contractors' better financial capacity enabled them to buy expensive software and maintain staff training. Overall, the case companies were not planning to develop their IT-based management systems to accommodate project/network members. System compatibility was favoured but nobody was making any efforts to achieve it. When first companies do, they need to take into account that system compatibility requires the concurrent building of collaborative relationships with networked members.
The **detailed findings** of the benchmarking process in terms of the max VCMF model as the measurement tool and the **consecutive recommendations** are presented by the seven subsystems of the sub-dimensions as follows:

1. **Project owner (client) relations management** with a PORMS is based on the use of CRM software. The current basis consisted of the use of Excel sheets to list and document current clients and in part also potential clients. Many passive companies relied on their good reputation as a means of attracting clients to contact them. In the future, CM firms could design a strategy for approaching new

clients and a strategy for maintaining long-term client relationships via follow-up surveys, fairs and marketing schemes.

2. **Project offering and bidding management** with a POBMS involves the use of product models for the in-house preparation of WBSs, the buying of BoQs and cost estimates from consultants as well as the use of the Internet for sending and receiving bidding documents. Currently, the case companies prepared their WBSs from procured 3D models or product models according to their predefined lists of work packages. The CM contractors were accustomed to buying BoQs from special consultants and prepared in-house cost estimates based on their own core competencies. In the future, CM firms could ensure IT-based compatibility with their contractors and subcontractors in order to fully exploit the Internet and other digital means for documentation management.

3. **Project design and engineering management** with a PDEMS enables the attainment of building designs as product models and the engagement of SSCs early in detailed design of their bid packages. Currently, the case companies procured design services (as a tradition) and there were no expectations to engage subcontractors with detailed design. The case companies eagerly experimented with the procurement of product models in pilot projects. Only a few companies had created product modelling libraries. In the future, CM firms could proceed with product model libraries and expand them in order to procure 3D models and convert them in-house to product models by using software such as ArchiCAD.

4. **Networked project procurement management** with a NPPMS enables the development and maintenance of lists of systems and services to be procured and matching lists of qualified members of a competitive network. The case companies had realised the benefits of developing such IT-based management subsystems. Many case companies also updated their lists of contractors and subcontractors and matched the qualified ones for each project. In the future, CM firms could maintain their lists of (inter)national contractors and subcontractors as a crucial step to assist in finding and matching the qualified ones with each project.

5. **Construction planning, execution and control management** with a CPECMS involves the preparation of a process model for planning and scheduling a project, engaging SSCs with scheduling their own work packages and detailed activity planning. All the case companies considered the cost estimation as one of their core competencies. The case companies were readily using and experimenting with available, advanced software for project planning, scheduling and control. In the future, CM firms could fully exploit newly developed cost estimation software that is compatible with product modelling software in order to extract cost information straight from product models for better cost estimation and control.

6. **Commissioning and after-sales management** with a CASSMS enables the preparation of as-built product models of finished projects and the submission of such models to clients for life cycle management. Only some case companies assisted clients by advising upon how and where to acquire FM services. In the future, CM firms could incorporate this subsystem into their PM/CM systems mainly because the provision of or the assistance in providing FM services to clients could increase their competitiveness in the market.

7. **Network nurturing management** with a NNMS involves IT-based directories for listing contractors and subcontractors and finding potential network members that match work-specific requirements as well as specifying necessary training, allocating workloads to preferred contractors and subcontractors to maintain long-term relationships. The case companies readily maintained electronic lists with broad information of their contractors and subcontractors but they did not search for new potential members actively. In the future, CM firms could also provide training to develop their network members' competencies to produce innovative building solutions and to allocate workloads for preferred contractors and subcontractors in order to maintain and enhance their collaborative relationships in the short and long term.

The **second dimension of virtuality** accommodates the outsourcing of functional units and real project work as part of becoming a flat leading firm within the VCMF. The empirical findings show that case companies' average scores varied 2.6-3.5. This can be explained in a sense that (i) the current outsourcing strategies concern mainly construction work, and the

most case companies considered functional units such as cost estimation to be one of their core competencies. Only the preparation of BoQs was widely outsourced. (ii) Both the CM contractors and the CM consultants preferred to maintain in-house, experienced PM staff in order to avoid any difficulties in finding right staff for future projects. Any advancement towards higher degrees of outsourcing requires companies to change their procurement strategies. Larger and fewer work packages are to be procured from among SSCs and the outsourcing of functions and project staff more in order to become as flat and lean as possible and to reduce fixed costs.

The **detailed findings** of the benchmarking process and the **consecutive recommendations** are presented through the four sub-dimensions as follows:

1. The **outsourcing of project organisations and teams** implies that the subsequent lead firms hire project teams from experienced staff pools. The most case companies maintained their experienced, permanent staff as their core competencies so that they could guarantee quality performance and avoid bottlenecks due to a lack of experienced staff. In the future, CM firms could encourage members within site organisations such as site managers, engineers, supervisors, etc. to become freelancers, while providing high incentives in order to maintain long work relationships and reduce fixed costs.

2. The **outsourcing of design and engineering services** implies that subsequent lead firms procure such services from specialist A/Es, even when firms provide project development and D-B services. Project designs are procured as product models and libraries are used to develop product models both by specialist A/Es and in-house staff. The case companies had been outsourcing such services for a long time (as a tradition) and also procuring designs as product models or 3D models that they converted in-house to product models. In the future, CM firms could also develop their own product model libraries and resource and cost model libraries that are compatible with other subsystems and models.

3. The **outsourcing of project work packages** implies that subsequent lead firms break projects down into large work packages (systems) and procure them from a predefined list of SSCs. The most case companies prepared their WBSs in-house according to

predefined lists of work packages (50-100, 100-300, 300-1000) depending on project sizes and procured them according to predefined lists of subcontractors. Only a few case companies suggested the breaking of their projects into big packages such as frames and the consecutive package-based procurement from among SSCs. In the future, CM firms could break projects down into larger work packages as part of a new strategy to attract and work with SSCs and benefit from their special, modularised know-how.

4. The **outsourcing of functional units** implies that subsequent lead firms procure BoQs, cost estimates, financing, production plans and schedules from specialists. The CM contractors were accustomed to buying BoQs, yet kept the in-house cost estimation as one of their core competencies. They also had the in-house bookkeeping. The case companies performed detailed in-house project activity planning and scheduling as well as incorporated such plans into their master schedules and production plans due to uncertainty involved in the use of incapable smaller subcontractors. In the future, CM firms could extend their outsourcing strategies to cover both functional units and project work as well as turn to SSCs as core providers. This is because emerging SSCs are more capable of maintaining IT system compatibility due to their better capabilities, resources and having maintained long-term collaboration.

The **third dimension of virtuality** accommodates collaboration and relationships between a lead firm and its competitive network of SSCs. The empirical findings show that the average scores of case companies varied 3.0-3.6. The CM firms scored high in their collaboration strategies with the designers (3.5-4.0) mainly because they wanted to maintain the long-term relationships with their network of A/Es (as a tradition, design services are always procured in Finland). However, the most case companies did not arrange training or promise future workloads to their networked contractors and subcontractors in order to maintain long-term relationships. This explains the rather low average scores (2.0-3.5). Only the two CM contractors maintained short-term contracts with some material suppliers for cost benefits. All the case companies kept a network of three to five members with informal, collaborative relationships as a prerequisite for enhancing competition and getting the best offers for their bid packages. All the case companies stressed trust as part of maintaining long-term yet informal relationships with their network members (3.0-3.8).

In the future, interested companies need to upgrade their collaboration strategies towards active networking and long-term collaboration with preferred SSCs. This in turn implies changing their procurement strategies to bigger, more attractive work packages as well as developing and nurturing their networks with a new portfolio of selected members to maintain competitiveness and include training for their network members in order to enhance efficiency among these members.

The **detailed findings** of the benchmarking process and the **consecutive recommendations** are presented through the three sub-dimensions as follows:

1. A **collaboration strategy with designers** is the key area of the management of the VCMF. The case companies readily maintained long-term relationships with their network of A/Es as design services are always procured in the Finnish building sector. The case companies, in an attempt to benefit from A/Es that understand their companies' visions and project requirements, maintained good collaborative relationships. In the future, CM firms could broaden and even enhance collaboration with A/Es by coordinated efforts to build up joint BCIM libraries.

2. A **collaboration strategy with SSCs** is the critical area of the management of the VCMF in terms of allocating workloads to SSCs, arranging training to enhance work efficiency and maintaining long-term relationships based on trust. The most case companies did not assume any responsibilities related to the allocation of workloads to their contractors and subcontractors. Whilst they considered that training would be vital to increase their contractors and subcontractors efficiency, the case companies did not do much to provide training. Almost all the case companies considered trust as one important factor for longer-term collaboration. In the future, CM firms could upgrade their procurement strategies to bigger work packages that could be attractive to SSCS and they could also adopt annual agreements as part of their collaboration strategies with SSCs and specialised material providers. CM firms could consider training for their preferred network members as a means of building more trust and longer collaboration.

3. **Formal and informal relationships between a lead member and networked members** is one of the key areas in

managing the VCMF. The case companies preferred to maintain informal collaborative relationships and develop competition when procuring contractors and subcontractors in order to get the best offers. In the future, a preferred strategy of CM firms would be to maintain an informal but close relationship with each of preferred members and an arm's length relationship with each of less frequent members, taking into consideration that trust enhancement is needed to enable such informal relationships.

6.5.4 Future applications in the real world

At the outset, this study began with the intention of providing some structure into a chaotic world of virtuality in the context of construction industries. The main aim was to develop a dimension of virtuality and design the two VCMF-related models so as to provide firms with initial guidelines on how to deal with such challenges that are inherent in becoming virtual. The adoption of these two models vis-à-vis real world scenarios could provide firm management with **order, structuring and directions** for determining the types and degrees of virtual operations that are appropriate to their given circumstances. This study can provide a basis and a starting point for thinking processes concerning what virtuality entails.

The study provides a **blueprint** that helps CM firms determine individual virtual requirements. For example, firm management may have an insight that a capability to collaborate virtually needs to be advanced in order to develop attractive projects. After the determination of the need, the management determines the availability of applications that would enable this development and change in such terms as upgraded IT infrastructure. It is also in the best interests of firms to sponsor future research into the three dimensions of the designed virtuality model so that (i) a detailed picture will emerge concerning these dimensions and the key factors affecting the applicability of each one, and (ii) practitioners' focus will centre the types of virtual dimension(s) that would support a given endeavour. In addition, (iii) the applications of an IT-based, integrated project and network management system should be developed so that firms will gain a realistic understanding of how to apply its seven subsystems and what desired and risky consequences will be.

It is suggested that firms providing CM services should carry out **more systematic market research** into relevant building sectors both in

Finland and abroad, as part of the advancement and development of their virtuality along the outsourcing dimension and in the nurturing of their competitive networks of contractors, suppliers and emerging SSCs. The results of such research would help in formulating attractive sourcing decisions, combining services or work packages geographically under each contract and discovering the availability of competent service providers.

6.5.5 Implications to researchers

As the **future real-life applications of the two models of virtuality**, it is recommended that future researchers build on these two models. The models offer testable dimensions and applicable subsystems. Researchers are advised to apply these models in real world cases and provide bases from which to expand into more detailed research topics and problems which are specific to virtual construction.

Concerning **further research on the two models**, this thesis provides a basis for the categorisation of virtual dimensions but not the in-depth research needed about each dimension and its application. Further research is welcomed to deepen understanding of factors/issues and strategic moves needed in different circumstances.

From the perspective of **the construction industries and future R&D**, it is recommended that firms support and/or take part in R&D that supports their needs and guarantees a return on investment to compensate for development costs. The seven related recommendations are as follows:

(i) The application of generic solutions which have no prior construction contexts and, thus, the learning from other industries (manufacturing, shipbuilding, aerospace, etc.), the working together with them as well as the adoption and/or the adaptation of their work methods to the construction industry.

(ii) Instead of breakthrough solutions, a realistic roadmap for a change process to enable the smooth transition of the industry from a traditional way of working to new ways of virtual working, via many incremental steps and consecutive successful outcomes.

(iii) Many software tools that are used cannot be thrown away. Therefore, this requires careful research and the realistic development of new software tools so as to be able to update and

integrate older versions as well as use existing technologies in intelligent ways.

(iv) There is a need for more research on interfaces between software available on the market and data exchange between them. When professionals use CAD, cost estimating and PM software, so they need to be able to share and reuse project information more effectively. In turn, researchers should consider today's implementation problems when looking for future solutions.

(v) R&D in the construction industry should focus on prototyping like other industries do in order to have better opportunities for the fast commercialisation of the results of successful prototyping.

(vi) There is a need for practical applications that solve problems, which points out to needs to consider users' requirements in thorough and detailed ways.

(vii) Researchers should focus on investigating and developing new technologies as well as avoiding consecutive introductions at premature stages.

7. SUMMARY

7.1 Setting and key results of the study

The emergence of VOs and other new models of coordination and cooperation have been enabled by the exploitation of advanced ICT. Scientific researchers have become principal investigators of this phenomenon. In turn, national construction industries are highly fragmented and many fundamental changes are pushing construction companies to radically review their business strategies, products and services. Herein, the strategic exploitation of ICT is seen as an enabler in solving the problems industries face.

This study has the **dual focus**, i.e. (i) a generic focus on VOs, addressing questions like "What does virtual mean?" and "How are organisations virtually structured and managed?" and (ii) an applied focus on CM firms in the Finnish building sector. In the early 1990s, the deep recession in Finland led to the establishment of CM competitive pressures. Many traditional building contractors changed and complemented their strategies by adopting a vision that can be characterised as a “virtual contractor” enabled by a strong IT infrastructure and ICT developments in the 2000s.

Thus, the main **research questions** posed in this study are as follows: "Why and how should companies virtualise CM services?", "How can we assess and measure the level of virtuality in CM firms?" and "How can such virtual CM firms be managed?" Hence, **the main objective** of this study is twofold: (i) to choose the relevant dimensions and design a model of virtuality, and (ii) to design a model of the maximum virtual CM firm with its supporting management system. Primarily, the three-dimensional virtuality model is designed for restructuring and strategising CM firms for virtual business performance in the context of the Finnish construction industry. The max VCMF model, with its IT-based integrated management system, is designed as the frame of reference and the tool for measuring

actual degrees of virtuality of CM firms. The **research assumptions** underlying the model design are as follows: (i) a flat organisation of a virtual CM firm is achieved by outsourcing functional units and real construction work, (ii) effective collaboration is managed with the new types of members, i.e. a competitive network of SSCs, and (iii) the integration of the management system of the maximum virtual CM firm is enabled via the three-part BCIM. The **research methodology** was planned to ensure the successful conduct of the model design and the benchmarking process. The **constructive research approach** (Kasanen et al. 1993) was selected and applied to the phasing of this study. The research problem and its solution are based on both the generic, theoretical knowledge about virtuality and the contextual knowledge about the traditional and virtual practices and the developments in the focal context of the Finnish construction industry. Both the theoretical problem and the practical problem of virtualising a CM firm were approached by the pre-planning and the actual design of the two novel models as the theoretical constructs and the investigation of their applicability in the focal context.

The **purpose of the foundational literature review** was to become familiar with the roots of the research problem, find out what has been achieved in this respect as the verified solutions and learn some new insights that could be applied to develop and synthesise new solutions applicable to the focal, national construction industry. The generic literature review was important in order to understand virtuality as a phenomenon and its applicability across industries, identifying the core concepts such as the core competence strategy, the outsourcing and the networking that were adopted as the theoretical bases for the virtuality model design, as well as identifying such applied models such as the virtual cube that could be adapted to the model design in this study. In turn, the understanding of the background of the contextual problem to be investigated and solved also required the concentrated review of the CM literature and the literature on virtuality concerning the construction industry. This contextual review provided some insights into what has been developed in virtualisation at the project level and what is lacking concerning virtualisation at the firm level.

The **three-dimensional virtuality** is herein designed based on the selected theoretical bases and the results of the preliminary investigation of virtuality within the Finnish construction industry. The dimensions are as follows: (1) an IT-based integrated management system, (2) outsourced operations and (3) collaborative, competitive networking. Together, they

capture and enable the static and dynamic aspects of operating and managing the max VCMF. Any CM firm can plan and advance its virtuality along one, two, or all of the three dimensions of virtuality. Along the **first dimension of a collaborative IT-based management system,** CM firms can achieve virtualisation by managing dynamic and rapid changes, creating and deploying intellectual and knowledge assets as well as sourcing tangible and physical assets from within their complex networks of relationships. The scope of virtual management encompasses project work, client relationships and competitive network members. All this can be supported by integrated ICT platforms. Along the **second dimension of outsourcing,** CM firms can virtualise themselves by outsourcing functional units and real project work to achieve organisational flatness and to swiftly configure a partial network every time a new project-specific opportunity arises. Along the **third dimension of competitive networking,** CM firms can aim **at organising virtually and contracting effectively for project-specific capabilities** through a network of designers, suppliers and subcontractors. Such operating requires the management of portfolio forms of collaboration between the core of the virtualised CM firm and the competitive network of SSCs, designers and a staff pool. Each dimension guides and manages the virtualisation of the particular aspects of a firm's performance, yet the three dimensions are intertwined so that collectively they enable virtualisation at both the firm level and the project level.

The **max VCMF model** is defined as an operation mode along the three dimensions of virtuality. The max VCMF is assumed to be a virtual CM firm which operates by VCMF *modus operandi* and exhibits the highest characteristics within the three-dimensional virtuality. The max VCMF model is used as the reference model to benchmark CM firms and as the tool to measure their actual degrees of virtuality. The max VCMF model is designed due to an absence of a virtual, best practice CM firm in the real world and defined to be a dynamic network of collaborating, geographically dispersed independent firms that reconfigure around a lead member/core. It is a purposeful system that consists of actors (organisations, individuals), resources (core competencies) and activities. Relationships between actors are structured by a purpose, connectivity, boundaries and ICT. Its essence lies in its flexibility to adapt to fast changing businesses and dealing with complexity and uncertainty. The life cycle of the max VCMF goes through the four phases of identification (seeking members), formation (contracting), operation and termination. It is a **flat organisation** achieved by removing middle management, outsourcing functional units

such as design, engineering, cost estimation, financing, administration, site management and site engineering as well as project teams and project work. Its delivery system is based on **competitive networking**, i.e. it consists of a dynamic network of several SSCs who supply the same products and functional elements or services, designers and staff pool. The max VCMF is managed by an **IT–based network and project management system** with its seven subsystems that are integrated by the three-part BCIM and supported by the IIS. The two subsystems assist in effective CRM and network nurturing management by structuring firms' knowledge on current customers and network members with new information obtained via IS/IT systems for better relationship management. The five PM subsystems assist in providing enhanced PM services by integrating SSCs' project work with the core's project operations via product, resource and cost as well as process models and by sharing and managing project information via the IIS.

7.2 Conduct and contribution of the study

This study was conducted by adopting the constructive research approach (Kasanen et al. 1993) and relying on its research procedures. The operational measures are documented in detail in this report so any interested scholars and readers can check the accuracy of every step. The reviews of the generic and contextual literature enabled the definition of the knowledge gap and the shedding of light onto the research problem. The critical problem of how to virtualise CM firms and how to manage such new virtual entities was chosen, mainly because the researcher anticipated such problems will soon arise and be experienced by practitioners in their daily life as a result of newly adopted IT-based strategies and the re-engineering of management processes.

Based on the sound theoretical bases and the results of the initial empirical investigation in the Finnish construction context, the three-dimensional virtuality model and the max VCMF model were designed. The applicability of the three-dimensional model in terms of the max VCMF model as the tool for measuring the actual degrees of virtuality was investigated by adopting the qualitative research approach, i.e. the benchmarking process. This is because qualitative data has advantages over quantitative data in enabling the understanding of shared meanings of practitioners, especially in terms of such a little understood phenomenon. The benchmarking process consisted of the semi-structured interviews with the top and project managers of the ten case companies from the Finnish

construction industry and the assessment of the case companies against the max VCMF by the questionnaires used by the interviewees themselves. These methodological choices are evident as it is still today impossible to think that the designed models and the constructs could be adopted by practicing managers and their exploitation could be followed up as a real-life case study.

The results of the data analysis of the collected empirical data indicated that the three dimensions of virtuality and their sub-dimensions are sufficient to obtain the quantitative values of the phenomenon under observation. In this sense, the semi-structured interviews and the self-assessment questionnaires were sufficient to yield such quantitative results. The accuracy of the interview-based data was maintained by involving the ten interviewees in the self-assessment of the degrees of virtuality of their respective case companies.

This study **contributes** to the existing, generic and applied theoretical knowledge as follows. The three-dimensional virtuality model has some novel, generic features. It is herein posited that the adoption of the model assists CM firms in analysing the key aspects along the three dimensions of virtuality at the firm level and the project level and gaining necessary insights into how to choose, design and execute their virtualisation strategies. It is claimed that the three-dimensional virtuality model is also applicable in the case of other business contexts. In turn, the max VCMF model is the novel theoretical construct. However, the results of the empirical benchmarking process indicated the modest applicability of the max VCMF model as the tool for measuring the actual degrees of virtuality in CM firms. The max VCMF's management system provides some insights into what CM firms need when developing their traditional management systems into the virtual ones.

7.3 Suggestions for future studies and applications

The key suggestions for future studies are put forth in order to further advance the elements of the three-dimensional virtuality model and those of the max VCMF model across many contexts of national CM practitioners.

Future complementary studies are needed on each dimension of virtuality and its application in order to gain the in-depth understanding of factors and strategic moves needed along each dimension and in the different circumstances of application. Such findings can assist CM firms in

determining their individual virtual requirements and how to go about fulfilling these requirements. The viable applications of the models can be supported by future studies that are sponsored by CM firms themselves.

Pilot research as a series of case research studies are also needed in the future. In this study, the IT-based management system model could not yet be tested, mainly because of large risks that are inherent in applying such a system to real-life management. Thus, pilot research and test projects could be carried out in many national and international contexts to advance the theoretical construct and its practical usefulness, especially through the testing of the applicability of the BCIMs and model libraries as the enabling part of the seven management subsystems and their integration

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APPENDIX 1.

INTERVIEWER'S ASSESSMENT QUESTIONNAIRE

HAASTATTELU/YRITYKSEN JA PROJEKTIEN JOHTAMISJÄRJESTELMÄT TALONRAKENNUSALALLA SUOMESSA

INTERVIEW/SYSTEMS FOR MANAGING COMPANIES AND BUILDING PROJECTS IN FINLAND

Name of case company:

Name of interviewee:

Position of interviewee:

Contact information of interviewee:

PART 1. Integrated collaborative management sub-systems

1. How do you approach potential clients and manage client relationships?
   - How do you take care of the client's requirements before and during the project? Who is responsible of this process?
   - How do you see the relations with your existing and potential new clients? As a one-time experience or a long-term relationship?
   - What software package do you use for CRM, if any?

2. How do you manage your bidding and contract processes?
   - What is your bidding and contracting system?
   - How do you prepare bidding packages? Do you also use external experts?
   - What software packages do you use?

3. How do you manage building design processes as part of your projects?
   - What is your system for procuring and managing building design services?
   - How do you use external design firms? What are contractual relationships?
   - What kind of own building design expertise (experts) do you have in-house?
   - What software packages do you use?

4. How do you manage your procurement processes?
   - What is your procurement management system? How do you break a building into procurement packages? How many packages do you normally use?
   - What is the scope of your bidding packages?
   - Do you use the same most reliable (sub)contractors and suppliers? If yes, do you have any criteria for the pre-qualification of these subcontractors/suppliers?
   - What packages are procured by the project team/office? What packages are procured normally by headquarters/procurement department?
   - What software packages do you use?

5. How do you plan and schedule your projects?
   - What is your project planning system?
   - How detailed is a master schedule in the beginning of a project?
   - Do you require your main subcontractors and suppliers to prepare their sub-schedules? If yes, how do you integrate sub-plans into a master schedule?
   - Do you develop any work programs while construction? Do you use any specific procedure for controlling the progress of scheduled activities?
   - What software packages do you use?

6. How do you control the costs of your projects?

   - What is your cost control system?
   - How detailed is a project budget in the beginning of a project?
   - What specific procedures do you use for controlling accumulating project costs? By procurement package?
   - What software packages do you use?

PART 2. Outsourced organisation and functions

A. Outsourcing project organisation and project team: (Formal/Informal)

1. Do you follow a special procurement strategy of a project organisation that is
   formal for your company or do you specify it per project such as:

   - Procurement of A/E firms(s)
   - Procurement of special consultancy firms

2. Does a project manager decide on a project team's procurement process or
   is it done together with top management?

   - Do you assign a project site manager from your company's staff pool, or do
     you employ him/her per project.

   - Do you assign a site engineer from your company's staff pool, or do you
     employ him/her per project.

   - Do you maintain a staff pool in your company for performing office-site
     co-ordination work.

B. Outsourcing functional units and real work

1. Project financing activities

- Do you finance your project(s), or do you buy financial services as a package per project? (Do request an explanation of how a financing process is achieved for a project)
- Do you depend on the same financial company in financing all your projects or do try to maintain a number of them.

2. Company administration tasks

- Do you perform administrative functions in-house by your own employees? What are these functions?
- If not, do you depend solely on service companies to provide you with administrative works (payroll, book keeping, etc.)?
- What are the functions that are obtained from among service providers?
- Do you maintain competition between service providers?

3. Project design tasks (Owner)

- Do you work with the same project design firm(s) on every project?
- Do you buy a design service as a package per project or perform part of it in-house?

- Do you specify a special software to be used by a design firm that would be compatible with your software to maintain a long term work relationship?

- Do you have any data model libraries?

4. Project cost estimating and bidding functions

- Do you buy your Bill of Quantities from special consultants?
- Do you buy your project's cost estimate from special consultancy companies or prepare it in-house?
- Do you prepare in-house your projects' Work Break Down structure?
- What are the work packages that you subcontract (outsource) in every project? Do you subcontract them with the same contractors?
- Could you estimate a percentage of the work contracted on your projects?
- Do you have a network of contractors with whom you maintain long-term work relationships?
- Do you depend on specialty system contractors in your work or traditional trade contractors?

5. Site management and supervisors:

- Do you assign a site manager per project or do you have permanent employed site managers?
- How do you employ and assign a supervisor/s per project?

6. Project production items:

- What is the scope of your bid packages?
- Do contractors perform the production planning of their work packages at the outset of each project? How detailed plans do you require?
- If your company performs project production planning, how far do you involve your contractors in a planning process, if any?

PART 3. Project collaboration

(How collaboration is achieved?)

- Does your company maintain a strategy to develop its own core competencies?
- Does your company assist its network partners in developing their own core competencies?

- Do you consider that providing of a steady workload to your network partners is necessary to maintain long-term collaboration?
- Is it important for your company that its network partners assume independence in their relationships with one another?
- What is the extent to which contracts, rules and regulations are used in your co-operation with your network partners?

- How important is it for your company that trust can replace formal contractual relationships?

- Do you force a collaboration contract/network contract in order to maintain a network of contractors that you work with?
- Do you consider trust as an alternative to collaboration contracts in maintaining your network of contractors?
- When you are outsourcing your functions, do you work on a 1-1 basis or a 1-open basis?

APPENDIX 2.

INTERVIEWEE'S SELF-ASSESSMENT QUESTIONNAIRE

INTERVIEW/SYSTEMS FOR MANAGING COMPANIES AND BUILDING PROJECTS IN FINLAND

- Integrated collaborative virtual project management systems
- Outsourced organisation and functions in a virtual organisation setting
- Collaboration in a virtual organisation setting

Name of case company:

Name of interviewee:

Position of interviewee:

Contact information of interviewee:

1st DIMENSION: INTEGRATED COLLABORATIVE MANAGE-MENT SUB-SYSTEMS OF A VIRTUAL ORGANISATION

1. **Project Owner Management sub-system POMS**

(i) Leading member: It enhances services through a pre-emptive expert relation development with existing and potential clients.

a. Approaching clients' needs by visualising them in a 3D format (product model) in terms of designing, visualising ( ).

b. Company management and project managers are getting involved in seeking new clients with special projects needs ( ).

c. Developing a special marketing scheme to keep in touch and satisfy old and new clients ( ).

d. Considering client relationships as the long term relationships ( ).

(ii) IS sub-system: provides real time information for generating and updating the lists of clients, contacts, etc.

5. A software package is used to prepare and update the lists of current and potential clients ( ).

1 very low, 2 low, 3 average, 4 high, 5 very high.

2. <u>Project Offering and Bidding Management sub-system POBMS</u>

(i) Leading member (VCMF): Top management of Leading member makes all decisions concerning breaking down work, buying Bills of Quantities and distributing packages to SSCs.

a. Leading member performs work breakdown structures and prepares work packages based on a product model prepared by a building designer ( ).

b. Leading member buys Bills of Quantities & cost estimates from specialist consultants ( ).

c. Leading member distributes bid packages to a set of SSCs via Internet ( ).

d. Leading member receives and decides among SSCs' packaged bids ( ).

(ii) Special system contractors (SSCs): They contribute to the detailed design of their bidding packages and bid on a whole system package

a. A SSC bids on a whole package including the design, development, and installation ( ) .

b. A SSC contributes to the detailed design of its bid package via a product model prepared by a building designer ( ).

c. A SSC sends its bid to Leading member via Internet ( ).

(iii) IS sub-system: A product model is prepared by a building designer, while a resource and cost model, and a process model are prepared by Leading member

a. A building designer prepares a building product model based on the requirements of a client ( ).

b. A product model is accessed by SSCs for the inputs of their bid packages and detailed designs to update a product model ( ).

c. A resource and cost model is prepared by Leading member based on a product model ( ).

d. A process model (a master schedule) is prepared by Leading member based on a product model ( ).

e. A process model becomes the basis to prepare detailed activity schedules by SSCs of their work packages ( ).

1 very low, 2 low, 3 average, 4 high, 5 very high.

3. <u>Project Design and Engineering Management sub-system PDEMS</u>

(i) Leading member: Leading member outsources a product model from a preferred network of A/E companies as the core of this sub-system to enable the exchange and change of project information with SSCs.

a. A leading member always outsources project design services from its competitive network ( ).

b. A leading member selects a building designer after a bidding process or negotiation with a preferred A/E.

c. A leading member performs design management by its assigned project manager ( )

(ii) **Special system contractors (SSCs):** They contribute to the detailed design of their bidding packages.

a. A SSC contributes to the detailed design of its bid package via a product model prepared by a building designer ( ).

b. A SSC assists in improving pre-construction constructability by giving their design feed-back to a designer ( ).

c. A SSC gives its real-time feed-back regarding design changes and adaptations through design layout reviews and the identification of design conflicts ( ).

(iii) IS sub-system: A full product model is prepared by an architect/engineer by a compatible software/application.

a. A product model of a building (product) is prepared by a architect/engineer ( ).

b. A product model is accessed by SSCs for the inputs of their bid packages and detailed designs to update a product model ( ).

c. Pre-construction reviews are made as sub-reviews per bid package by a designer together with SSCs early in a project to identify design conflicts ( ).

1 very low, 2 low, 3 average, 4 high, 5 very high.

4. <u>Networked Project Procurement Management sub-system NPPMS</u>

(i) Leading member (VCMF): It outsources processes and services which are not part of its own core processes.

a. A leading member notifies members of its competitive network of SSCs via internet to post their bids/offers for the work packages ( )

b. A leading member expects the SSCs to provide tailored solution as part of their bid packages ( )

(ii) IS sub-system: It provides networked SSCs with an internal arena to compete and come up with a best offer.

a. A system provides a list of services and processes to be procured ( ).

b. A system provides a list of current and potential qualified contractors ( ).

1 very low, 2 low, 3 average, 4 high, 5 very high.

5. Construction Planning, Execution, and Control Management sub-system CPECMS

(i) Leading member: Its management system contains sub-systems for (i) planning and scheduling as well as (ii) cost control.

a. Leading member prepares a process model (a master schedule) for a project in terms of systems and packages to be performed by SSCs ( ).

b. Leading member together with SSCs use the short-term rolling window planning to extend a master schedule into work programs when a construction phase starts. Work programs are prepared for a specific period ahead on specific intervals ( )

(ii) Special system contractors SSCs: They perform the detailed planning and scheduling of their bid packages.

a. A SSC prepares a detailed activity plan/schedule of the work in its bid package and incorporates it in a master schedule ( ).

(iii) IS sub-system: It provides information for procurement, construction tasks and site activities with their dependencies, durations and costs.

a. A process plan as a master plan is produced in terms of system packages to be performed by SSCs ( ).

b. Design changes are fed into a process model so that up-to-date execution plans and schedules are available on an on-going basis ( ).

c. Cost information is fed into a process model based on actual expenditures among SSCs and subcontractors on site ( ).

1 very low, 2 low, 3 average, 4 high, 5 very high.

6. Commissioning and After-Sales Services Management sub-system CASSMS

(ii) Leading member: It maintains a life-cycle management system to its client through the outsourcing (and procuring) a service package.

a. Leading member does not provide itself life-cycle services, instead it outsources commissioning plus after-sales services to a qualified SSC ( ).

b. Leading member hands over an updated product model to a client as a basis for managing and acquiring life-cycle services in the future ( ).

(ii) IS sub-system: It provides information to select a qualified SSC to provide commissioning and life-cycle services.

a. Information (such as profile directories) collected from other management sub-systems is used to find a match between the required performance and the commissioning plus after-sales services over the life-cycle of a building ( ).

1 very low, 2 low, 3 average, 4 high, 5 very high

7. **Network Nurturing Management sub-system NNMS**

(i) Leading member: It develops the competencies of its network in order to produce innovative building solutions.

a. Leading member develops the expertise of its collaborative network ( ).

b. Leading member provides a workload for its collaborative network members ( ).

(ii) IS sub-system: It provides information for new partner(s) search.

a. It is used for developing directories including information about preferred companies, their profiles such as competencies, performance histories ( ).

1 very low, 2 low, 3 average, 4 high, 5 very high.

2nd DIMENSION: OUTSOURCED ORGANISATION & FUNCTIONS IN A VIRTUAL ORGANISATION SETTING

A virtual construction management firm (VCMF) is a flat organisation with only top management and project management levels. Project organisations and teams are outsourced as to a

networked pool of organisations and staff as entrepreneurs. All functional units are outsourced to a network of specialty contractors.

1. <u>Outsourcing project organisation and team</u>

(i) Leading member develops a formal procurement strategy for procuring a project organisation and teams:

a. Leading member procures a site manager and a site engineer from a staff pool working as entrepreneurs ( ).

1 very low, 2 low, 3 average, 4 high, 5 very high.

2. <u>Outsourcing work packages</u>

(ii) Leading member prepares a work breakdown structure and procures packages from within its network of SSCs:

a. Leading member prepares a work break down structure WBS per project ( ).

b. Leading member breaks a project into work packages with big scopes to be bid and

be implemented by its network of SSCs ( ).

c. Leading member sends packages to SSCs via Internet and it receives their bids via Internet, too ( ).

1 very low, 2 low, 3 average, 4 high, 5 very high.

3. <u>Outsourcing design and engineering</u>

(iii) Leading member outsources design and engineering services from its network of

architects and engineers:

a. Leading member buys design services as a package per project ( ).

b. Leading member relies on an informal network of designers to work with ( ).

c. Leading member uses a compatible software with its designer(s) to main long term

work relationships ( ).

1 very low, 2 low, 3 average, 4 high, 5 very high.

4. <u>Outsourcing functional units and real work</u>

(iv) Leading member outsources the functional units:

a. Leading member buys project financing services as a package per project by using reliable, trusted financing companies with whom it had long work histories ( ).

b. Leading member buys its company administration functions (payroll, book keeping, etc.) from special services companies ( ).

c. Leading member buys Bill of quantities and cost estimates from a reliable

consultant(s) per project ( ).

d. SSCs are responsible for planning their work production methods and procuring resources for implementing their own work packages ( ).

1 very low, 2 low, 3 average, 4 high, 5 very high.

3rd DIMENSION: PROJECT COLLABORATION IN A VIRTUAL ORGANISATION SETTING

Leading member manages a portfolio of forms of collaboration based on trust to achieve a high degree of virtuality. Collaboration is enhanced between Leading member and its competitive network of SSCs, designers and a staff pool.

(i) Leading member collaborates with a network of architects and engineers for obtaining design work:

a. Leading member has informal collaboration with its network of architects and designers ( ).

(ii) Leading member connects to two or more SSCs that supply same systems, modules and functional elements in order to enhance internal competition and obtain better performance:

a. Leading member assists its collaborative network in developing their core

competencies ( ).

b. Leading member considers that providing steady workloads to its collaborative network members is necessary for long-term collaboration ( ).

c. Leading member relies on it collaborative network members in outsourcing all its

functional units ( ).

d. Leading member considers trust is important to build better relationships with its

collaborative network members ( ).

(iii) Leading member collaborates informally on a 1-few basis with its competitive

network of SSCs when procuring work packages:

a. Leading member depends on a 1-few collaboration with its competitive network in

order to maintain competition for better performance ( ).

b. Leading member does not sign any formal collaborative contracts to maintain future

work relationships with its SSCs and product suppliers ( ).

1 very low, 2 low, 3 average, 4 high, 5 very high

APPENDIX 3.

DESCRIPTION TABLES

Table 1

Company name	Score	Description of dimension Description of sub-dimension
Max VCMF	5.0	
Case 1		
Case 2		
Case 3		
Case 4		
Case 5		
Case 6		
Case 7		
Case 8		
Case 9		
Case 10		

Table 2

Dimension no./ Subdimension name	Max VCMF	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
	5.0										
	5.0										
	5.0										
	5.0										
	5.0										
	5.0										
	5.0										
score	5.0										

Table 3

Dimension of Virtuality	Max VCMF	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
IT based management sub-systems	5										
Outsourced project organization & functions	5										
Collaborations & networking	5										

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