ENLARGED ROLE OF SPECIALTY SYSTEM CONTRACTORS IN A FULL VIRTUAL (DIGITALIZED) SUPPLY NETWORK

Wafa Alsakin[1], Teppo Salmikivi[2], and Juhani Kiiras[3]

ABSTRACT

In the virtual building environment, all construction services are produced by a dynamic and fully digitalized network of service suppliers. Herein, a construction management services company is fully virtualized. A Virtual Construction Management Services Company (VCMSC) is a dynamic competitive network of collaborating contractors and designers which reconfigure around a leading project management (PM) member. A VCMSC company has outsourced all of its functional units (including cost estimation). In turn, a Special Systems Contractor (SSC) is defined to be a combination of the design, manufacturing, delivery, and installation of the building systems and elements by various specialty contractors. Suppliers and subcontractors can adopt herein a new enlarged role with the incentives for system development, innovations, and new delivery packages. The aim of the paper is to introduce how a VCMSC uses IS/IT, product, and process models in multi-bidding and multi-contracting systems to minimize communications failures and difficult construction trade interfaces. Therefore, the Work Breakdown Structure (WBS) is prepared with a scope of bid packages that are large and versatile enough so the packages can become a viable target for a specialty network. In order to utilize the SSCs' expertise in real time, the product model is used during the design management to provide a platform for the contractors' contribution. The product model allows the effective exchange and change of project information early enough to improve constructability especially during pre-construction and design development phases. The wide use of special systems contracting becomes an effective tool for creating fully virtual supply networks. A VCMSC is a purely theoretical construct, but it may help companies across (inter)national construction industries to understand and even improve their virtual properties

KEY WORDS

Building, special systems contracting, virtual construction management services company.

[1] Doctoral Candidate, MSc, TKK Helsinki University of Technology, Construction Economics and Management, P.O. Box 2100, FIN-02015 TKK, Finland, Phone +358 41 4541330, FAX +358 9 451 3758, walsakin@abo.fi

[2] Head of Construction Management, Lic.Sc, MSc, University of Helsinki, Technical Department, Lic.Sc, MSc, Helsinki University of Technology, Technical Department, teppo.salmikivi@helsinki.fi

[3] Professor, TKK Helsinki University of Technology, Construction Economics and Management, P.O. Box 2100, FIN-02015 TKK, Finland, Phone +358 40 5630732, FAX +358 9 451 3758, juhani.kiiras@tkk.fi

INTRODUCTION

The paper is part of the ongoing research program for **the development of new theoretical concepts and systems** for managing an ideal, fully virtual construction company. The program is carried out in the unit of Construction Economics and Management (TKK/CEM) at the Helsinki University of Technology. Prior this paper, we have conceptualized the virtuality of construction company to a modest extent in the focal context [Kiiras, J. & Huovinen, P. 2004], [Alsakini, W. 2004], [Alsakini, W., Kiiras, J., and Huovinen 2005]. The idea of a fully virtual construction company is based on the good experiences of the key specialized construction management (CM) companies in Finland. In **CM contracting**, all the procurement packages will be bought from the competitive market. A client (an owner) makes all final decisions about all design solutions and each subcontractor and supplier. Detailed design, procurement, and construction works are performed concurrently [Kiiras, J., Stenroos, V., Oyegoke, A. 2002].

In addition, we align with the key contributions within the virtual organization literature. A virtual organization as an evolving model is rooted in the paradigm of network organizations [Marshall, P. et al 2001], [Travica, B. 1997], [Virtual organization net 2004]. It resembles a dynamic network that facilitates the discovery and the configuration of core competencies in a value chain, which in theory leads to an optimal value creation process [Sabeel, W. et al 2002]. **A virtual company** is considered an economically purposeful system composed of a set of interrelated elements, i.e. actors, resources, and activities [Sabeel, W. et al 2002]. It has the ability to alter a value creation process [Franke, U. J. 2000] through a concept of switching [Mowshowitz, A. 1999]. A fully virtual construction company has a flat and virtual organization and it purchases all works and services from its competitive network of special system contractors (SSCs). Special Systems Contracting is developed to advance the adoption of extended building contracts with the design and engineering, manufacturing, delivery, and the instalment of building systems or functional elements by various specialty contractors. Tendering is based on the know-how of contractors and selection criteria include performance, quality, price, and the life cycle costs of the system. Various subcontractors, service providers, and suppliers can adopt a new enlarged role of a special system contractor with incentives for system development, innovations, and new delivery packages. The penetration of the special system contracting will, in turn, advance effective networking and possibilities for contractors with life cycle services. The defined virtual CM company uses SSs in its projects. A fully competitive network must contain fewer suppliers than in the case of a traditional general contractor, but they must have a larger scope.

In general contract forms, owners (clients) receive fixed prices and schedules. However, their possibilities to influence processes or to make changes during construction stages are limited. Any change in design involves negotiations between a client and a contractor concerning costs and a schedule. The implied lack of competition infers that changes during later stages can become expensive. An owner's designers finalize all designs, drawings, and specifications, on the basis of which competitive bidding is arranged. In turn, a general contractor arranges competitive bidding among second-tier subcontractors, and so on. All these competition stages are based on the cheapest products that meet an owner's

requirements. All available suitable products and good operational performance cannot be obtained through this low bid chain. Instead, owners are left with all low bid problems such as weak quality, chained price competition, decisions made prematurely, and low flexibility for possible design changes [Kiiras, J., Kruus, M. 2005].

When the CM contract forms are adopted, better performance can be achieved through the selection procedures as well as a freedom of contractors and suppliers to offer their solutions and assume the responsibilities as part of actual contracts [Kiiras, J., Kruus, M. 2005].

The aim of this paper in to introduce how a VCMC uses the networked SSCs to maximize performance competition and how it uses IS/IT, internet, product, and process models to minimize common project communication failures and difficult trade interfaces. A product model acts as a platform for SSCs' contributions to design and engineering and a process model for SSCs' plans and schedules and control. A VCMSC is a purely theoretical construct, but it can help any type of project based companies to understand their virtual properties as future benefits.

MAIN FEATURES OF A VCMSC

Herein, a traditional construction contractor is transformed toward **a flat, pooled, and virtual organization** through outsourcing. There are several flat features, i.e. all the middle levels of management are removed and all functional units such as cost estimation, procurement, and building design services are outsourced [Kiiras, J., Huovinen, P. 2004]. Prior internal project staff is encouraged to act as entrepreneurs who form a staff pool from which a virtualized contractor assigns key staff to each project. A VCMSC concentrates on a limited number of professional clients and large projects. The remaining flat and virtual organization consists of company management and experienced project managers only.

For each project, one project manager is assigned to carry the PM responsibilities. For the overall design phase, a project manager acts as a consultant and leads a design team together with client representatives, an architect, various engineers, and consultants. During the bid or proposal preparation, a project manager heads the buying of estimation services and the allocation of SSC procurement packages via a competitive network. When a particular bid is won, a project manager leads the detailed design and engineering of the chosen SSCs, makes a master schedule, mobilizes a site organization from a staff pool, and manages the construction phase with the help of detailed activity plans and schedules prepared by the SCCs. The latter have larger responsibilities in design, planning, and control, too.

All long-term one-on-one partnering has so far resulted in a loss of real competitiveness sooner or later. The profitable performance of a VCMSC's network will be endangered without internal competition. Thus, the delivery system of a VCMSC is based on **competitive networking** [Kiiras, J., Huovinen, P. 2004]. A competitive network of SSCs is needed to ensure the product flexibility, design changes flexibility, short delivery times, and the concurrency of design, procurement, and the construction works on site. Networked members and external suppliers are motivated to add value-for-client money through their systems and product expertise, whereas a VCMSC (i.e. a leading member) focuses on enhancing its CM and PM expertise. A procurement strategy is revised to allow the extension of delivery and contract scopes, a decrease in a number of deliveries per project, and the

creation of network with the most important suppliers. A leading member networks with several SSCs [Tommelein, I. D & Ballard, G. 1997] that supply the same systems, functional building elements, or services (Figure 1) [Kiiras, J., Huovinen, P. 2004]. More planning and control activity is given to each systems contractor over its own system delivery and finger pointing is reduced in the event of interfacing contractors with different priorities.

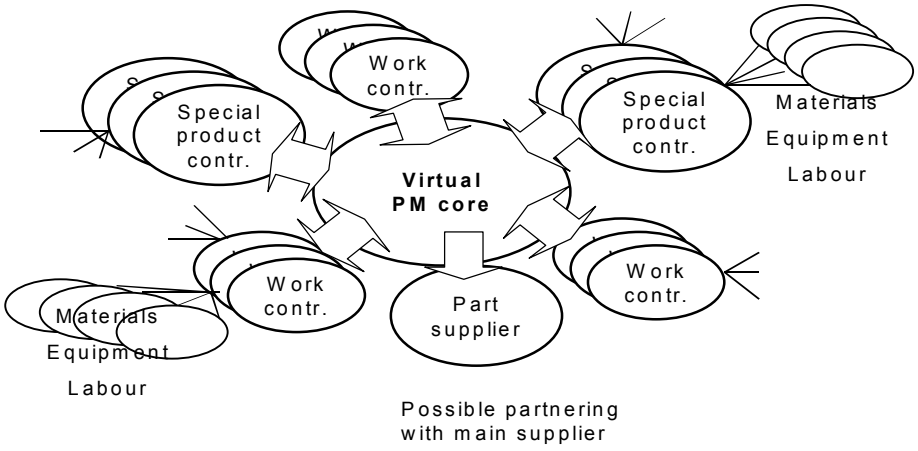

Figure 1: Delivery system of a VCMSC based on a leading member and competitive networking (Kiiras and Huovinen 2004).

MANAGEMENT SYSTEM OF A VCMSC

In the context of construction management (CM), individual practitioners are needed to perform various advanced CM services for owners. A vast range of expertise required perform all CM services and demand for timely CM performance on projects precludes the performance of complete CM services by an individual firm [Haltenhoff, C. E. 1998). The management system of a VCMSC consists of seven sub-systems [Alsakini, W., Kiiras, J., Huovinen, P. 2005].

(i) **Project owner relations management system (PORMS)** enables a VCMSC to enhance the quality of its services through the pre-emptive expert relationship building with the targeted existing and potential new clients (owners). A VCMSC generates and updates a list of the most attractive clients. Company management and project managers act as client accounts for ensuring future work.

(ii) **Project offering and bidding management system (POBMS)** enables a VCMSC to collaborate with its competitive network of SSCs. The leading member performs the work scope breakdown and prepares a list of systems bid packages, buys bills of quantities and a cost estimate from an expert consultant(s), and distributes the bid packages to the networked SSCs for the bid preparation. As a rule, each package will be bid by at least three members, who have room in work load, available staff, resources, and an interest to submit a proposal. One of many innovations of the CM system is multi-bidding and multi-contracting which minimizes frequent and difficult construction trade interfaces [Alsakini, W., Kiiras, J., Huovinen, P. 2005].

(iii) **Project design and engineering management system (PDEMS)** is designed to improve constructability by providing the networked SSCs to contribute early enough to the detailed design of the systems or bid packages that are allocated to each of SSCs. The leading member establishes in every project a product model as the platform to which all project stakeholders can have real-time access to the most recent design documents. The SSCs make and give their parts of the product model back to the leading member based on the production model. A traditional pre-construction constructability review is divided into concurrent sub-reviews that take place by design packages. Designers get on time the real-time feedback regarding design changes and adaptations through the design layout reviews and the identification of design conflicts. So SSCs solve constructability problems during the construction phase.

(iv) **Project procurement management system (PPMS)** provides the SSCs with the internal arena to compete effectively in order to come up with the best integrated offering. The leading member is able to move towards the outsourcing of those processes which are not part of its own core skills. When a project opportunity arises, the leading partner notifies the network members via Internet data transfer to post their offers/bids, selects the bids, and notifies the winning bidders, who will in return take part in the detailed design or do it altogether and provide the tailored solutions as part of their bid packages.

(v) **Construction, execution, and control management system (CECMS)** enables the leading member to provide an advanced planning in which the coarse master plan, the detailed activity planning are completed just before the beginning of each SSC work. Short time rolling windows are used trough the whole project. All detailed scheduling is done by the SSCs. They control their own activities, too. Corrections are made immediately. If work stops in one workplace, it is jumped over and a new team will be allocated. The PM plans **a master plan**, which contains the main systems or packages to be performed without the details. For control purposes, the critical path and milestones are used. Each of the SSCs plans just before a start its activity plans/schedules which are re-integrated as sub-schedules into the real-time master schedule. An activity plan is prepared in the way that allows each activity to be presented in a rolling window to show what sub-system and work will be executed on site and how.

(vi) **Commissioning and after sales services management system (CASSMS)** enables the leading member to provide the client with a facility management (FM) system by procuring the FM services package. A VCMSC does not participate itself in the FM services. Instead, it plans and prepares the contract of the FM package for the client.

(vii) **Network nurturing management system (NNMS)** enables the leading member both to develop the competences of its network and renew its membership. The leading member may choose the core VCMSC team project by project based on a “fit-for-purpose” strategy, i.e. the required expertise and competences are determined and the necessary functional areas are specified for the project in hand. The leading member seeks new possible SSCs to the network, gives all needed software to them, and gives training in use.

SPECIALTY SYSTEM CONTRACTORS IN PERFORMANCE BASED SPECILTY SYSTEMS CONTRACTING

In the building market in Finland, the use of the SSC model has resulted in the contracts in which subcontractors (or suppliers) take the responsibility for the system design and detailed engineering, the manufacturing, and the installation of the building systems or elements including the in-use-performance of the system as defined by the owner (client). Special systems contracting transfers a part of design responsibilities to specialty system contractors who couple them with their product design and production planning, respectively.

When competition is based on design solutions, material choices, and production efficiency, the SSC model does not discriminate construction techniques and materials. Competition expands from production know-how to system know-how and from details to a total solution. In competing with solutions, it is possible for SSCs to come up with more innovations and develop their production. In the SSC model, competition includes also system and technical solutions [Salmikivi, T. 2005].

In comparison, SSCs are responsible for a wider scope of work in Finland than traditional specialty contractors do in the USA [Tommelein and Ballard 1997]. The latter are mainly interested in the design phase of products, but the former are actually responsible for designing and engineering their systems, too. The definitions for the term system in the SSC model vary in the literature. At its widest, a system contains the whole building as an individual system. At its smallest, a system includes only e.g. the mounting and planning of a small part of construction work, like concrete reinforcing. In the VCMSC model, the specialty systems contracting is limited to refer only to larger systems [Salmikivi, T. 2005].

To serve the clients, a VCMC divides a building according to the principles of open building, into the systems of **the permanent base building** (support or shell and core) and **the flexible space in-fills**. The design and realization of space in-fills are accomplished in accordance with the users' space requirements. Concerning the independence of design and production, the systems are divided into base building systems, permanent space systems, technical building services systems, flexible space systems, and site area systems. Base building contains ground work, foundations and a building frame, a 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 the interior area (technical core). Space in-fills are carried out by departments, which are designed and procured as separate SSC contracts. So space in-fill contains both the construction and technical systems design and allows the integration of the production techniques with the space parts.

IS/IT SYSTEMS FOR A VCMSC AND SPECIALTY SYSTEMS CONTRACTORS

There are two main questions when IS/IT strategies are designed for virtual networks: (1) how to be flexible enough for dynamic environment and changing network and (2) integrate all members of network at the same time to "one" business entity. A VCMSC's IS/IT strategy can be simply defined as follows: to select and hire or buy well-known commercial software or applications (that fulfill the managerial requirements), distribute them to the competitive network partners and the staff pool, and the SSCs' network is nurtured by IT training. To buy or hire all software solves the flexibility problem. The distribution and

training of common applications to all members tries to give simple solution to the well-known software integration problem.

A IS/IT system that facilitates the realization of the business strategy of a VCMSC (flat, pooled, outsourced functions, competitive network) is based on using the Internet and some kind of Intranet/Extranet. The Extranet is used to allow controlled access from the outside for trusted customers and/or networked partners to a VCMSC's database for specific business purposes and to connect members to the private Intranet competitive network via the web. The conceptual IS/IT solutions for the three main management sub-systems of a VCMSC communicating with SSCs are all of the same kind as follows.

Project offering and bidding management system (POBMS) enables the leading member to collaborate with a competitive network of SSCs. A project scope needs to be large and versatile enough so that the project becomes a viable target for this virtual specialty network. The information sub-system is set to support the performance of **POBMS** by providing the required information for the leading member to perform the work scope breakdown and prepare a list of bid packages based on a product model (prepared by the designer). The leading member buys a bill of quantities and a cost estimate based on this work breakdown from an expert consultant(s) via Internet, then distributes the bid packages to the networked SSCs for the bid preparation via Internet as well (Figure 2).

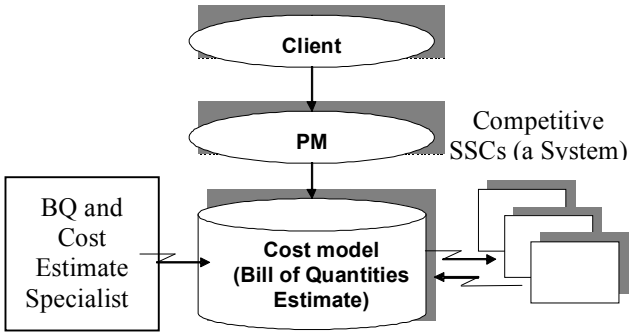

Figure 2: IS/IT sub-system of a VCMSC to facilitate the project offering and bidding management system (POBMS)

Project design and engineering management system (PDEMS) is designed to improve constructability by providing the networked SSCs with a platform to contribute early enough to the detailed design of the systems or project packages that are allocated to each of SSCs. This information sub-system combines or links engineering analysis to CAD to produce a full product model which combines both an architectural model and building simulation models. The leading member establishes **a product model** through which project stake-holders can have real-time access to the most recent design documents. The product model enables the effective exchange and change of project information. This is achieved as designers get the real-time feedback regarding design changes and adaptations from the

networked SSC through the design layout reviews and the identification of design conflicts (Figure 3).

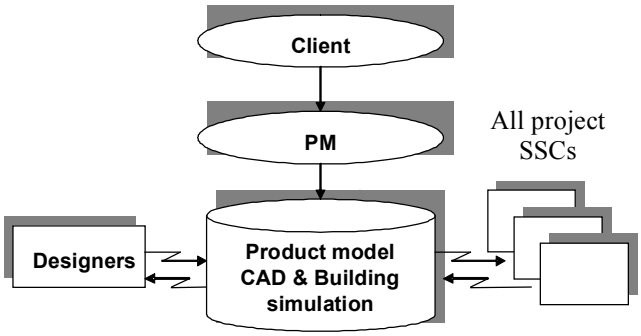

Figure 3: IS/IT sub-system for a VCMSC to facilitate the project design and engineering management system (PDEMS)

Project procurement management system (PPMS) enables the leading member to select a number of SSCs whose work histories and profiles match the required expertise. The bid packages are sent for bidding and received back via Internet (Figure 4).

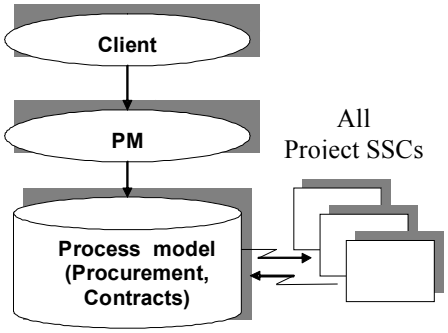

Figure 4: IS/IT sub-system for a VCMSC to facilitate the project procurement management system (PPMS)

Construction, execution, and control management system (CECMS) contains the planning and scheduling system and the cost control system as a **process model** containing the activities, their dependencies, durations, resources, and costs. This process model produces a master plan developed by a VCMSC and contains the main systems or packages to be performed by SSCs. Each SSC plans its activity plan and schedule and integrates them into the real time master schedule in the process model (Figure 5).

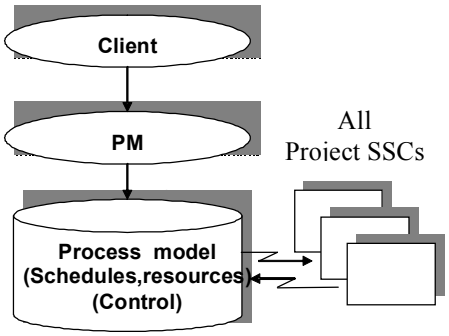

Figure 5: IS/IT sub-system for a VCMSC's construction, scheduling, execution, and control management system (CSECMS)

CONCLUSION

A VCMSC has a flat, pooled, and virtual organization, i.e. all middle levels of management are removed and all functional units, even cost estimation, are outsourced. Project staff act as entrepreneurs who form a staff pool from which a VCMSC assigns key staff to each project separately. The remaining flat and virtual organization consists of company management and experienced project managers only. This flat virtual organization needs a network with less partners and a larger scope. The introduced SSCs have a large scope and they act independent and perform much of the management work normally accomplished by general contractors and client representatives. When using SSCs, a VCMSC minimizes trade interfaces and decreases communication failures.

An ideal and theoretical VCMSC implies the use of information and communication technology as an enabler to facilitate its performance with its members. The flat organization and virtual business strategy cannot be managed without using the Internet as the basic tool for communication, common compatible software applications as a tool for integration. The Extranet is used to allow controlled access from the outside for trusted customers and/or networked partners to a VCMSC's database for specific business purposes via the web. A VCMSC should distribute common applications to networked SSCs and train them, too. All management sub-systems of a VCMSC are designed in the same way; the PM from a VCSMC leads the project, offering, estimating, design, planning, and control, but most of those activities themselves are performed by SSCs.

The management and the distribution of project information include fully digitalized information extracted from both a project's product and process models prepared for design, planning, and control purposes. Product and process models are developed as tools to enable information sharing, exchange, and interoperability between competitive network members of a VCMSC. Centralized access to an information storage, a project databank, enables a project group to utilize updated data in real time.

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