# Managing the Design and Delivery Processes of Building Services under Construction Management Contracts

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## 1 Introduction

Many owners begin the construction phases of their building projects either before users are known or when users are not yet ready to specify detailed design requirements for spaces. It is not easy to change from traditional sequential design and construction practices (a chain model) to **a construction management (CM) fast track approach** in which design and construction are overlapping (a concurrent model). In Finland, exceptionally difficult problems are being encountered during the working design process and the selection of a delivery method associated with building services (BS) or HEPAC systems under CM contracts. BS problems are usually caused by the established practices, i.e. users must specify their detailed design requirements for spaces before construction works begin. Examples of causes of such problems include: (a) a standard scope of design tasks, (b) software based design, (c) design compensation practices, and (d) traditional delivery forms.

This paper is a part of the **"Developing a Design System for CM Contracts" (FinSUKE) research project** conducted in the Construction Economics and Management Unit at the Helsinki University of Technology. The purpose is to develop design management procedures for concurrent CM projects, i.e. for an environment in which the particular uses of the building spaces are specified not until during the construction phase. So far, the sub-results have been presented at seven international conferences. The underlying FinSUKE Open Building concept is introduced in Saari et al. [2006]. The second paper focuses on the management of flexible programming and overall design [Saari & Raveala 2006].

**The Open Building concept** enables the division of a building into two parts: a permanent base building (or a 'support') and modifiable spaces (or an 'infill'). The basic idea is to establish the principles for dividing and combining subsystems in a way that minimizes their interdependencies, i.e. subsystems are transformed without a need to redesign or renew the entire building. The same principles have been found to be applicable in concurrent design process management. So far, the

applications of generic open building principles have primarily involved residential buildings. In turn, the FinSUKE project is focused on commercial and other premises. Both the prospective and retrospective tests concerning the selected properties of University of Helsinki have demonstrated that the principles of Open Building are effective in managing BS design processes and selecting the related delivery method as well as in managing the projects as a whole. It has been easy to separate the design and the procurement of the permanent element (e.g. exterior walls) and the 'infill' element (e.g. interior walls) from each other. However, the application of the principles of Open Building seems to be more challenging in the case of BS. Traditionally, HEPAC systems are perceived as one whole which cannot be divided into a permanent base building and a modifiable infill.

Thus, **the aim of this paper** is introduce the new FinSUKE solutions for managing a working drawing process and selecting a delivery method for building services and HEPAC installations, based on the division of a building into its two primary constituents as follows, under CM contracts.

Besides the Open Building concept, some key principles inherent in set based design [Sobek et al. 1999; Bogus 2004] and those of overdesign [Ballard 2000; Bogus 2004] have been adopted. In particular, the overdesign concept in FinSUKE research means the dimensioning of the permanent support according to the targeted range of space variance.

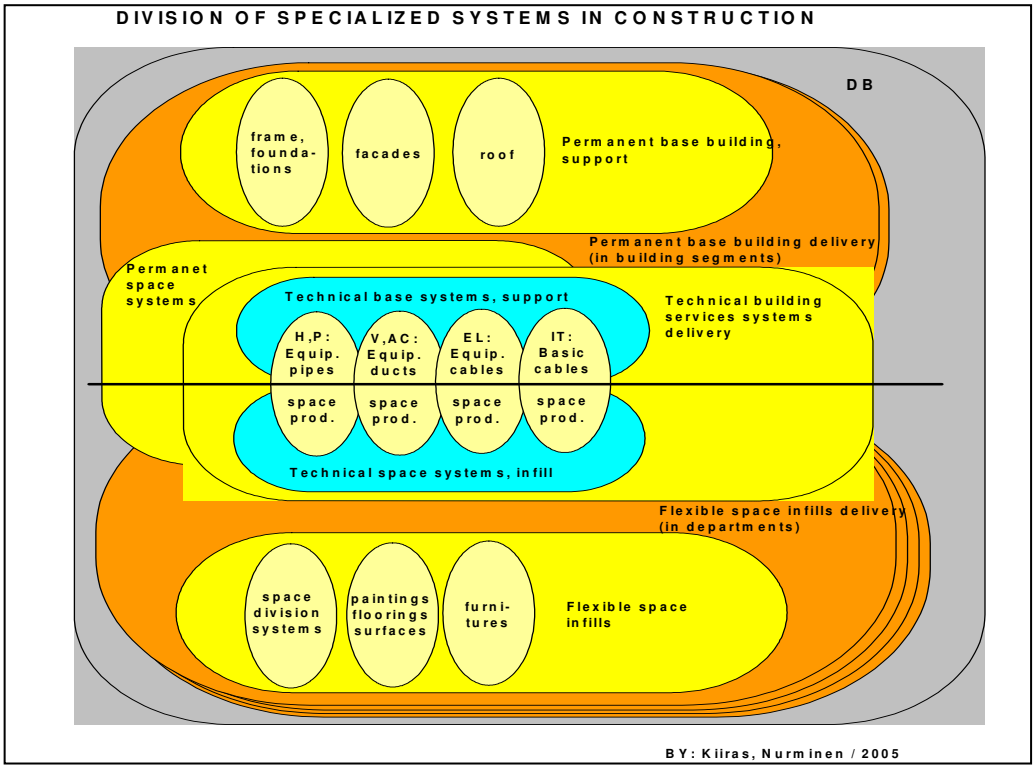


**Figure 1. Dividing building services and construction into a permanent base building and a modifiable infill.**

## 2 Flexible design process

The essential feature of managing flexible building projects is that **flexibility targets** are defined for the division of a building into a permanent base element and a modifiable element as well as for the allocation of a space programme into a set of particular open spaces [Saari & Raveala 2006]. **The overall design phase** is divided into: the preparation of the proposals and the actual overall design. In a proposal phase, alternative design solutions are examined for both the permanent base building and modifiable spaces. The overall design documents match to the selected permanent base building. In turn, alternative space concepts cover a set of the modiable infills. A borderline between the

permanent support and the modifiable infill is determined building by building. Typically, much attention is placed to building safety systems like fire alarm or sprinkler installations if the first space areas will be taken into use while the infills of other space areas are still under construction.

In the FinSUKE model, **a working drawings preparation process** is managed by design packages. A CM-based model includes a list of standardized design packages with their basic contents [Kruus & Kiiras 2005]. The criteria for design packages formation involves the principles of Open Building, not a trade based procurement breakdown.

Working drawings for modifiable spaces are completed concurrently with a selection of users (e.g. tenants). Design changes occur only if a particular space-specific decision leads to a change in the permanent support. This happens when space decisions does not fit into a range of variation of space requirements or the borderline between the permanent support and the modifiable infill were defined poorly.

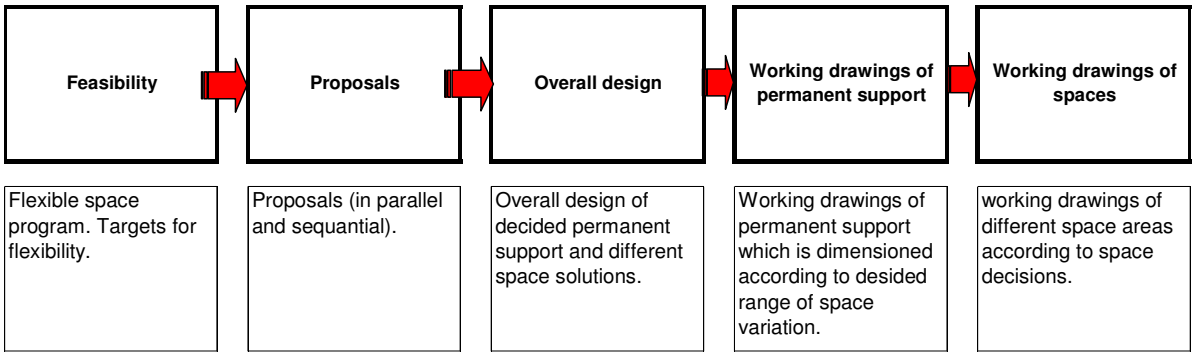


**Figure 2. Design process of building services.**

## 3 Selection of a delivery method for flexible building services

Five alternative delivery methods for BS are compiled in Table 1. In **(1) Building Services Management (BSM) contracts,** an owner hires a building services contractor to work like a CM contractor. A BSM contractor makes a procurement breakdown in which the total works are divided into HEPAC systems and products, installation works, or a combination of those. Based on the working drawings, the installation works could be performed by a BSM contractor's own labor force with a compensation as a lump sum. An alternative solution is to use additional installation works contractors. In the case of BS, there are many advantages when own labor force is relied upon, i.e. the ineffective and costly use of the labor is avoided by the pre-specified accounts for the installation work contracts.

In Finland, traditional delivery methods for building services involve **(2) lump sum prime trade contracts** under the coordination of a main contractor. All design documents are needed before the construction works start. These contracts cannot be applied to flexible projects where most space requirements are finalized during a construction phase. This hindrance is avoided by using design options, i.e. prices for modifiable space solutions (options) are specified as unit prices [Saari et al. 2006]. In **(3) building services multiple contracts,** a client (a CM contractor or an owner) splits a procurement breakdown in many parts (contracts) based on trades, infill areas, building phases, or a combination of these. In **(4) building services design and build (D&B) contracts**, design is incorporated in the same contract [Pernu 1997]. A D&B contract form enhances the evaluation of alternative design solutions by a client. The responsibilities over the life-cycles of the HEPAC systems can also be incorporated to a BS D&B contract. This form is suitable for projects where space requirements are known in the beginning and there is a plenty of time for a design phase.
In turn, **(5) space contracts** enable a fast and effective increase in contractors' resources. A particular space contract can combine an overall building design commitment with both civil construction works and HEPAC installation works. The permanent support can be constructed under the other contract

form (e.g. a traditional BS trade contract). In this way, a client avoids many problems inherent in a trade based procurement breakdown (e.g. when a large area needs to be completed with a short lead time, the control of the use of the various subcontractors' resources is lost).

| | 1 BS CM contracts | 2 Traditional BS contracts | 3 BS multiple contracts | 4 BS D&B contracts | 5 Space contracts |
|---|---|---|---|---|---|
| Description | Building services contract using CM principles | Traditional lump sum trades (HEPAC plus building automation) | Multiple contracts: trades, areas, building phase or a combination of these | Building services design & build contract | Building services procured with other works for the same spaces (space by space). |
| Procure-ment break-down | 20-60 | 1-4 | 7-15 | 1-2 | Particular space 1. Permanent support separately. |
| Budget, bargain | * Budget for a space concept<br>* Possible target price | * Lump sum, unit prices, options | * Multiple trades with lump sum | * Lump sum, unit prices, options | * Lump sum, unit prices, options |

**Table 1. Alternative delivery methods for building services.**

## 4 Case Biomedicum 2

Biomedicum 2 was developed and commissioned by the Technical Department of the University of Helsinki in order to provide versatile facilities for different hi-tech medical enterprises for lease. The case project consisted of 11 000 sqm enlargement for Biomedicum 1. The users were chosen before, during, and after the construction works. In particular, **a high variance inherent in user requirements** is being encountered during the life cycle of Biomedicum 2, i.e. the users' (tenants') research programs last only some years and, thus, new programs bring along changes in space requirements. The building was divided into a permanent support and a modifiable infill. The permanent support was designed to meet the targeted high range of space requirements variation. The five sets of the alternative solutions were developed for the modifiable infill. The decisive restrictive factor was the maximum numbers of the fume chambers to be placed in each section. When the space requirements were delayed, the BS working drawings could not be prepared as a continuous flow.

After the excavation works, the building construction works were carried out under a Finnish CM contract ("CM-at-risk"). The other possible delivery method could have been a CM Agency contract. The permanent support could have been constructed also under a lump sum contract (and the space areas under a separate set of space contracts). The delivery method for the building services was **a set of the BS CM contracts** assigned with the CM contractor. One of the BSM subcontractors is liable for the performance of each HEPAC system as a whole. The owner's prior experiences favored the selection of this hybrid CM contract form, i.e. it enabled to make many true quality-price choices.

## 5 Conclusions

Herein, the validity of the suggested FinSUKE model is dealt with in terms of **applicability**. Some key Finnish owners have had many negative experiences when trying to manage the working drawing processes and to select the optimal delivery method for BS (or HEPAC systems) in their CM based projects. In this paper, both some primising theoretical solutions for those problems are introduced and the outcomes of their testing are demonstrated with the help of one case project. In addition, the suggested FinSUKE model have been tested and found to be useful in refurbishment projects involving both historically valuable sites and those with a small range of space requirements variation. Likewise, the Open Building concept is applicable to such building projects where the first

users are readily known before actual construction begins. In some prior cases, it ensured that the permanent base building is dimensioned to allow the targeted range of user requirements variation.

**Some current software programs for HEPAC systems design** have caused problems for managing flexible working drawing processes. This software requires the detailed solutions of the modifiable spaces before the dimensioning of the permanent support. Thus, **new software** is needed for HEPAC design processes to allow the adoption of the suggested FinSUKE design principles.

Finally, **the chains of competition** can be compared between various contract forms. In lump sum general contracts, a chain of competition is long. For example, each HEPAC products and materials purchase must pass 3-4 price competitions. All these competition stages are based on the cheapest products that meet the owner's requirements [Kiiras et al. 2005]. The number of alternative eligible HEPAC products is reduced too much. Thus, these owners are left with all the low bid problems such as weak quality, chained price competition, decisions made prematurely, and low flexibility for possible design changes [Kiiras et al. 2002]. On the contrary, when the suggested BSM contracts are adopted, selection procedures result in high performance due to e.g. the freedom of BS providers to offer their most applicable solutions and to assume life cycle responsibility for the same.

In Biomedicum 2 case-study flexible working drawing process and delivery method selection was applied to enable flexibility in design and construction phase. Authors believe that presented flexible process enhance the **flexible design solutions** as well. In Biomedicum 2 case-study many flexible design solutions were used. For instance building services installations were integrated in precast concrete hollow-core slabs. When the building will be in use the changes for plumping and draining system could be done without disturbing neighbours above or below. Presented systematic process support the flexibility to design, construction and utilization phase.

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