ELECTRICAL SYSTEMS PROCUREMENT BY MEANS OF TARGET COSTING

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ABSTRACT

Electrical systems are typically procured through detailed drawings and specifications. In the case of an intense project timetable, the procurement process lacks time to commit the potential suppliers to the project and to compile precise and detailed design and bidding documents. This paper introduces methodology for preparing the tendering documents directly from the performance criteria set for electrical systems before the electrical design commences.

In Finland, target costing methodology in construction is based on a constructive Building Information Model (BIM) prior design. Component-level target costing uses performance criteria set for the spaces (such as 400 lux lighting) as initial information. The result with a BIM design is a priced bill of quantities that indicates the target cost for the future design process. In this paper, it has been used as a tendering document before the start of design.

For the most part, HVACE systems are composed of a producing element, a linking element, and a functional element. For instance, the elements in lighting are the switchboards, cables, and luminaires, and those in cooling are cooling units, pipes, and cooling beams. These elements can be modelled through building-information-modelling-based prior design.

In the case studies of this paper, the electrical systems suppliers were selected before the electrical design. The suppliers have given positive feedback because of the ease of tendering, opportunity to participate in the design, and possibility to schedule the work on their sites earlier. Managing the changing quantities in the contracts has been possible because of the unit pricing for costs. The target costing process and design steering during the design have ensured successful cost management.

KEYWORDS

Lean construction, open building, building flexibility, procurement, cost modelling, target costing, electrical systems.

INTRODUCTION

Traditional planning and building processes have not progressed alongside the needs of today's customers. There is desire to commence construction sooner than before, after the programming and during the design phase. A long implementation planning phase before one chooses contractors and starts construction is considered idle time that pushes back the return on investment and causes unnecessary costs. The principle

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of open building requires that implementation plans not be too complete when the contractor is being chosen. Plans are compiled only when the final users of the spaces in the building have committed. Customers want to reduce the total time of the building process and the wasted work and expenses caused by plans based on incomplete information.

In this paper, a new planning and procurement method is presented in which the procurement of the electrical systems can be done before implementation planning as reliably as possible and with only the information from the programming phase. The target costing process as used in Finland also produces the modelled information generated from programmatic data, prior to design. Component-level target costing models (TAKU^{TM} model), among other things, the bill of quantities for electrical systems. This can be used directly in a new procurement method and yield results that are accurate enough. Also, involving the contractor in the implementation planning as a party bringing its own expertise to the process improves the results of the method.

THE NORMAL PLANNING AND PROCUREMENT PROCESS (DESIGN AND BUY)

The usual planning procedure in Finland is as follows:

Figure 1: The normal planning and procurement process (design and buy)

PROGRAMMING

First, a project plan and target budget are prepared. They are based on needs and on the demands of the property-owner and user.

DESIGN FOR PROCUREMENT AND CONSTRUCTION

After that, precise plans that are ready for implementation are made. Supplying is handled according to these plans.

PROCUREMENT

The contractor counts the quantities of materials and work inputs from the plans, calculates the prices, and submits a tender. The number of tenders the builder receives depends on the market situation. The offer usually presents the total price also and sometimes some price specifications and unit prices too. Normally, the agreement is made with the contractor offering the lowest total price.

CONSTRUCTION

The chosen contractor realises the (sub-)contract in accordance with the plans made in the implementation planning phase.

PROBLEMS AND CHALLENGES IN THE NORMAL PROCESS

- Information is not necessarily final in the planning phase, so the basic data might be incorrect. This leads to errors in the plans (losses), which have to be corrected later. (Ballard and Koskela 1998, Saari et al. 2007)
- Correction of incorrect and inadequate plans in the implementation phase necessitates extra work and alterations (wasted work).
- Final drawing plans for implementation demand a lot of work and time. While these are being made, the project cannot proceed to the next phase, because contractors have not been chosen yet and the project has not reached the implementation phase. The time taken for this process unnecessarily pushes back the return on the estate-owner's investment. (Bogus 2004) This problem has been analysed in the doctoral thesis of Matti Kruus (2006): In many projects, customers have demanded shortening of the planning time by so much that making detailed electrical plans is not possible. These targets have included the hospital Coxa and also targets 1, 5, and 7, which are presented below, in the 'Results' section.
- Cross-function teams are essential in target value design (Ballard 2006) The expertise of the contractor cannot be utilised in the planning phase for development of the implementation solutions, because a contractor has not yet been chosen. Benefits from getting the contractor's feedback in the planning process are, therefore, lost with this method. (Ballard and Koskela 1998, Egan 1998)
- Quantity surveying is normally done in several potential contracting firms simultaneously. The work that goes into quantity surveying comes to about 70% of the work of preparing a tender (this information comes from the users of the BROKER calculation program (see http://www.mercus.net/). All the work done on quantity surveying is lost if the company in question loses the bidding competition. Finnish building associations (RAKLI, NSS, and STUL) have twice issued a statement in which they express a wish that procurement materials include reliable quantities of components.
- In an open-bidding context, users of the premises are often involved in later phases of the process. Having precise implementation plans before facility-users become involved goes against the principles of open building and would cause waste and redoing of work. (Habraken, 2003)
- If progress in the building phase is not guaranteed, often binding offers from contractors are sought, to ensure a decision to continue. If in the traditional model the project ends in the procurement phase, most of the planning costs have been tied up in the plans, because they are made ready for implementation. Thus the planning costs are wasted. This is why the owners have asked for a planning model in which the planning costs in the implementation phase are much less. In 'Results', target 2 features this demand.

A NEW PLANNING AND PROCUREMENT PROCESS (BUY AND DESIGN)

To compensate for the weaknesses in the traditional planning process and procurement method, a new method is proposed. In this method, reduction of loss is achieved, along with greater suitability for the demands of the real-estate business.

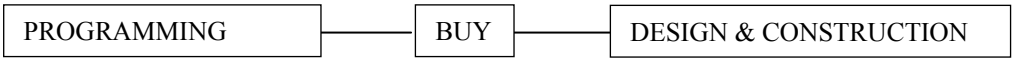

Figure 2: The new simplified 'buy and design' model

PROGRAMMING PHASE

The programming phase is the same as in the traditional model of operation.

PROCUREMENT MATERIAL

After the project planning phase, procurement material is compiled with the aid of the new developed procurement model.

- The time used for compilation of procurement materials should be as short as possible.
- Procurement is based on documents that are quick to prepare yet still contain enough extensive and reliable information for the tendering process.
- The information in the procurement material is equivalent to the component-level target costing information in the programming phase (Pennanen et al. 2008)
- The accuracy in the procurement is sufficient for the buyer's needs. The possibility must be left open for changes, so that standard modifications do not cause extra costs for the buyers.
- The tendering process is made as easy, reliable, and quick as possible. The set of materials is divided into parts, so it is easy to request subcontracting offers. Amounts are stated in the call for tenders. Thereby, a great deal of unnecessary counting is eliminated for the contractors.
- The procurement method must involve compiled statistics; that is, it is based on iterative units and lots, which can be taken as a basis for procurement in raw form even for different targets.
- Contract pricing is transparent, meaning that the contract price is made up of small, independent elements (for example, the electrical system) and units (such as the terminal equipment).

IMPLEMENTATION PLANNING AND BUILDING

Implementation plans (drawings) are compiled mainly in the building phase, when the contractor has been chosen and construction commences.

In new-building projects, there is enough time to carry out the electrical planning after contracts have been made, because those plans are not yet needed during the excavation and foundation work.

The contractor's knowledge both of implementation solutions and of procurements is a benefit. The contractor can guide the process of making implementation plans and also offer development suggestions.

Later in the building process, users and/or tenants participate more in the building process and have also fleshed out their needs, so these can be taken into consideration in the making of implementation plans, minimising wasted work. Also, tenants in some cases can make changes for their spaces before implementation planning.

BUILDING-INFORMATION-MODELLING PRIOR DESIGN

The modelling of bills of quantities has been developed in conjunction with target-costing-modelling-based prior design (Pennanen et al. 2008).

The TAKU^{TM} Building Information Model uses a constructive basis to determine the distributions of the building components. The information model's input information consists of the spaces needed by the client (200 m^2 library hall, 35 m^2 operating theatre, …) and the performance requirements the client sets for those spaces (internal temperature control to within 2°, 20 pneumatic outlets, 6 m height, 400 lux…). The model yields expected the life-cycle costs (investment plus maintenance costs) for new buildings or renovation projects.

For the most part, HVACE systems are composed of a producing element, a linking element, and a functional element. For instance, in lighting the elements are the switchboards, cables, and luminaires, and in cooling they are cooling units, pipes, and cooling beams. Functional elements can be modelled through local function information – e.g., the illuminance required in a specific space. Producing elements can be considered the sum of functional elements – e.g., the sum of the power of the luminaires. The quantities of linking elements are affected more by the overall design decisions, such as the grouping and connections of the spaces. However, the cost weight of the linking elements in comparison to functional elements and producing elements is quite low.

The application models building components hat can meet the customer requirements. The result is priced quantities for 'reference systems' that are on the market. An example of component-level modelling would be modelling of the number of luminaries by means of the formula $N = (E \times A) / (F \times n \times Uf \times Mf)$, where E is the illumination required, A is the size of the space, F is the efficiency of a lamp, n is the number of lamps and the other input factors describe the surfaces' absorption and the probability of not all of the lamps working. It is not necessary to prepare first a design solution to count the number of luminaries (or determine the size of the main switchboard, or…) if we know the client requirements (e.g., assembly hall of 1,200 m^2 or lighting at 600 lux), since the designers use the same formula to determine the number of luminaries.

Modelling for lifts is based on the waiting times demanded, round-trip-time, and peak handling capacity. Beam, slab, column, and foundation modelling is based on the ability demanded to accommodate functional loads, minimum-column-interval demands, information on the soil, etc.

THE PROCUREMENT METHOD

For this new planning and procurement process, a procurement method had to be established, in a completely new way.

In Finland, the electrification of buildings has been handled via grouping into standardised systems. These systems and their formation are presented in the publication S2010 - *Title list for electrical engineering* (Sähkötieto ry, 2012).

Each electro-technical system is a complete functioning unit that produces a certain service for the user, so the classification scheme is mostly consistent with the perspective of the client's performance need, which forms the basis for the target costing method.

For determination of prices, the system classification defined in electrical nomenclature document S2010 was not at a detailed enough level. To specify this, procurement definition by system was adopted. The price thus yielded was precise enough.

Unit quantities were chosen in terms of a specified procurement definition. A unit is a model of some system part. It is also the information that target costing modelling gives in the beginning, stemming from clients' needs.

The unit quantity is obtained in building information modelling without the traditional implementation planning and drawing.

The unit might be, for example, a socket outlet, for which the contractor states a unit price. The sum of the prices for all of these outlets together becomes the price for the whole socket outlet system. The unit here is not a real socket outlet but a model, which covers various kinds of socket outlets in the project (flush-mounted ones, surface-mounted ones, socket outlets in the installation tray, etc.).

The contractor figures an average price for a socket outlet, for which a combination of different socket outlets will be bought.

Technically different sockets must be modelled separately for price determination. The contractor gives a price for a normal socket outlet, 16 A three-phase socket outlet, 32 A three-phase socket outlet, etc.

Most of the important electro-technical systems by cost impact are unit-based or at least can be assigned a value by unit base, while other electrical systems are already approached as units. In the latter case, a system unit is assigned a total price and items are purchased in the quantity needed.

Still there are systems for which well-specified procurement information cannot be defined. Then one must compile a report, drawing, figure, or other document, which defines the system.

In this procurement method, each separate electrical system is procured such that it is most suitable for both the electrical system and the project, so that the tender price ends up as exact as possible.

Procurement methods such as this are used, for instance, for many industrial targets, and a procurement method based on units is in general use at least in Germany.

In Finland and in Sweden, the counting programs that contractors use do not completely respond to the new method's requirements, but their application for this method is easy.

The set of procurement materials is created as easily, reliably, and quickly as possible from documents of these types:

- Reports, Quantity lists, Figures and Preliminary drawings

The method eliminates the need to compile single-use, time-consuming, and hard-to-convert documents such as these:

- Final, exact implementation drawings
- Specific circuit diagrams
- Extensive layout designs

Procurement material can be considered as a mass of material and work hours that are used later in the building process as precise implementation plans dictate.

Changes to procurement prices, in either direction, are made via unit prices that are mentioned in the agreement. Other than unit-priced changes are made in the traditional way: charged at hourly rates or in terms of commissions.

RESULTS

Research work on the buy and design method is ongoing. However, the method has been used in seven building projects and the feedback from most of these is usable already. Interview-based research into the method is being performed also. The projects' status is as follows:

1. Office building 1
    - The building is finished
    - The procurement method was target costing project-management contract
2. Business centre
    - The building process was stopped in the planning phase
    - The procurement method was target costing project-management contract
3. Hospital/office/hotel
    - The building is finished
    - The procurement method was lump-sum contract
4. Dormitory/hotel
    - Work on the target was stopped but is now in progress again
    - The developer switched procurement method, opting for a traditional one
    - The procurement method is lump-sum contract
5. Office building 2
    - The building is finished
    - The procurement method was target costing project-management contract
6. Art museum
    - The building is in the implementation phase
    - The procurement method is lump-sum contract

7. Renovation of a radio house
    - The building is in its planning phase
    - The procurement method is lump-sum contract

PRELIMINARY AND APPROXIMATE RESULTS FOR THE ABOVE-MENTIONED BUILDINGS

- Office building 1

The budget was perfect. Bidding came in under the cost estimate. One change to the plans was made. One problem in the project was the change of the commercial floor into a restaurant. The floor was eliminated from the contract under unit pricing.

- Business centre

The building process was halted in the procurement phase, because no tenants had been found for this project. As a result of use of the method, unnecessary planning costs were saved, because many fewer documents were prepared for the procurement phase than usual. Savings came to about 30% of the total planning costs of the project, and about 50% of costs compared to plans if they were made in the traditional way for the procurement phase.

- Hospital/office/hotel

The extra work and change-related work required stemmed a great deal from both the original users and building-phase users. Changes in interior design caused considerable costs – these were not under control, because they had not been included in the pricing. The method operated impeccably, but not all of its possible benefits could be gained.

- Dormitory/hotel

The project was led and commissioned by a building company. Work on the target stopped because of architectural/environmental complaints. While the method functioned in an impeccable manner, the building company did not trust the results it had gained, because of contrasting information it had previously obtained. This is why it moved over to a traditional process. The planning and implementation process started again, and more results will be known later in 2013.

- Office building 2

With the new method, the financing was successful and the estimate was accurate. There was a lot of extra work and change-related work, because the property-owner let the tenants change the basic concept at almost no charge. The majority of the other tenant changes were charged to the tenants or were included in the rent. The implementation method would have served better if there had been more alternative solutions for the interior furnishings.

- Art museum

This target is a special wooden building target that has won an architecture competition. The procurement price exceeded the estimate, but the fault lay in the estimate. The mistake in the estimate was found during comparison between the

pricing and estimate. The first changes under this method have been made without any problems. More information is to be received in the course of 2013–2014.

- Renovation of a radio house

The target is in the tendering-process stage. Information on the procurement method will be received later in 2013.

FEEDBACK AND EXPERIENCES

Feedback will be collected systematically in forthcoming interviews, but some comments are ready.

Property-owners:

There is very little feedback from property-owners, because of the low number of projects employing this method. The most important aspect has been the adherence to goals and estimates. Owners indicated a desire for more alternative implementation solutions and product definitions now that the new procurement method easily allows that.

They wished to see the same method applied to other procurement targets also, such as HVAC systems.

Property-owners were very satisfied with the pricing transparency and with the ability for changes to the procurement to be made with the same unit prices later, during the building phase.

Builder consultants:

The new method is not compatible with the traditional documents and procedures. This causes extra work for consultants, which, in turn, creates a risk of mistakes.

Contractors:

The new method caused the most problems for contractors. Problems arose because the contractor's pricing method was not compatible with the method's pricing requirements. The contractor had to calculate the prices for units and larger entities again.

The situation became much easier when they prepared an offer in the next projects with the new method.

Special thanks were received because contractors did not have to perform quantity surveying, since the amounts were already stated, in the tendering materials. This reduced the contractor's risks in offer-making, because there were no more possibilities of mistakes in quantity surveys.

Some contractors said that this new method was a bad way of doing business for them (with fewer possibilities for charging for additional work as the drawings constantly change). On the other hand, contractors who had used the new method wished for new projects using this method.

Research continues, and the researchers will get more feedback from facility-owners and contractors in the coming months. The results will be published later.

CONCLUSIONS

The use of Buy and Design method has shortened the time needed for design and construction process of electric systems. Most of the final drawings can be done in

the beginning of construction phase. Usage of Buy and Design method does not lead to inflated cost even though drawings are not conclusive and final at the procurement phase. Customers and contractors think that the Buy and Design method is usable for construction and reduces waste.

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