DESIGNING TO TARGETS IN A TARGET COSTING PROCESS

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ABSTRACT

Traditional cost management determines the cost of the product based on its design and the estimated cost of realizing the design. Target costing acts upside down compared to traditional cost management:

The cost of the product is determined before design

The cost of the product is based on the customer's requirements on the product's performance and the customer's willingness and ability to pay for such performance. Willingness is based on the customer's business plan; i.e., on what the prospective product is worth to them.

The target costing process is focused in project definition (when target cost is determined) and design (when the functional targets and cost target will be achieved). This paper describes design steering, a methodology for managing design process to achieve target cost and purposed value for the customer. Design steering understands the nature of design in various stages and manages by knowledge and rapid feedback loops. Cost feedback is essential especially in the very early stages of design. Feedback can be generated by engaging multifunctional teams to support design. Rapid estimating and value monitoring can also be supported in the early stages by component level target costing produced by information modelling before design.

KEY WORDS

Target costing, Design, Cost modelling, BIM, Project management

INTRODUCTION

Target costing in construction is based on firm theory. Methodologies and applications have been developed to support the concept. Target costing in practise has proven to lead to proposed value and it has reduced waste (Pennanen, A., 2004; Ballard, 2009). However, we need to better understand, and hopefully improve, the methodology. A previous paper by the authors explained how to determine expected cost from programmatic data; an essential step in aligning client ends, means and constraints during project definition, and setting targets for scope, quality level, and conditions of satisfaction, which typically include cost and schedule (Pennanen & Ballard, 2008).

This paper is another contribution to target costing methodology. It describes design steering, a method for managing the design process to achieve targets. The method was developed by Haahtela Group and is in widespread use in Finland. The paper continues the exploration on designing to targets in construction. Previous literature on the topic include Ballard & Reiser, 2004; Pennanen, 2004; Pennanen et

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al., 2005; Ballard 2006; and Ballard, 2008. The paper consists of a description of the processes through which designer decisions change costs, and a description of the design steering methodology itself, followed by recommendations for future research.

The authors belong to a group of researchers developing and testing various aspects of target value design, the name adopted for the adaptation of product development's target costing to construction. Other approaches to designing to targets are in use elsewhere in the world, especially in the United States, and will be the topic of future publications.

STEERING DESIGN IS NOT DESIGNING

In the three decades from 1960 to 1990, in the Nordic countries, project management was concerned with the unpredictability of construction costs as design seemed to become more and more complex. Standardization was widely used to control costs (and quality, as well). If possible design solutions are limited from many to few, complexity decreases as well as cost variability. Standardization covered design from massing (type plans) and detailed design (type details) to manufacturing (standard prefabrication). Floor to floor height was 3 or 3.3 m, type plans and eaves details were chosen from manufacturer's library of standard designs, etc.

Standardization can be seen as designing. Some design solutions are done by public authorities, some by owners (type plans), some by manufacturers (floor to floor height with prefabricated units is 3.3 m), and some by contractors (standard eaves joints). Project designers take care of the rest. Some architects have become worried about shared design's impact on the quality of the urban environment (Roger Duffy 2010).

Through standardization, costs were successfully controlled and functional goals were achieved, yet finally the society and media have also become concerned about the architectural quality of the urban environment. As a result, for instance, the city of Helsinki has forbidden prefabrication of the external walls of buildings.

Although shared designing is needed (e.g. city planning vs. project planning), design steering manages design rather than designs. Management consist of functions such as planning objectives, staffing, leading, taking care of knowledge transfer, motivating, measuring and giving feedback. Steering design highlights designers' power to make design proposals but connects accountability to the power; only the client can increase the target cost. [4]

THEORIES OF MANAGING COMPLEX SOCIAL SYSTEMS

In the last 50 years, concepts like cybernetics emerged, a combination of servomechanism (feedback control systems) theory and information theory. Feedback control shows how a system can work towards goals and adapt to a changing environment. What is required is the ability to recognize the goal, to detect differences between the current situation and the goal, and actions that can reduce such differences (Simon 1996).

[4] Author's comment: Many designers feel this "Cardinal Rule of target costing" to be too strict. To clarify, target cost must never be exceeded but target cost can always be changed. It cannot be changed because the designers fail to find solutions fitting target cost and proposed functionality because the target cost has been set actually by the paying customer, the client. Target cost must be changed whenever the client wants to change the functionality of the building, even during design. The reason to change the performance of the building might be, for instance, changes in the business environment.

In simple cases the relation between disturbance, controlled system and outcome is known. In such cases the controller can plan actions to prevent unwanted outcome before the system starts to respond to the disturbance. In complex cases (e.g. social systems) it is not possible to predict how disturbance (different values, skills and wishes of people) will affect the system (client, PM, design team) and outcome (different design solutions, values, costs) and thus it is impossible to plan regulation based on anticipating a disturbance. A "closed loop feedback regulation" has the widest applicability when controlling such complex systems. In this type of feedback system the information takes a longer route; instead of measuring disturbance, the controller measures its effect through system to outcome (Ashby 1956).

The behavior of the steering system should be purposeful**,** it should resist and over ride the effects of outside disturbance and keep to its goals. So that the original aims can be achieved, the steering system needs a feedback loop, dampers (negative) and amplifiers (positive) (Principia Cybernetica 1997). Positive feedback alone leads to divergent behavior, indefinite expansion and a snowball effect. Too much complexity needs to be damped, so that the number of alternative states is kept manageable.

A controller can be formed so that in the controller there is a representation of the controlled system (Principia Cybernetica 1996). Cybernetics also concerns the principle of learning (Beer 1966). By studying the process to be steered, a model (representation) which describes reality as closely as needed is formed. The regulator (agent) which steers the process also uses the model. The influence of the regulator's steering on the achievement of the goal is measured and further used to fine-tune the model. In this way the regulator will give better results in the future. The feedback loop, the regulator and the regulator's program together form the steering system.

If a closed loop control is designed, information flow from the present state to the controller must be adequate and fast enough. If the flow is inadequate the controller cannot plan the actions. If it is too slow, the controlled will go on creating new states before the controller can act. If there are restrictions in the flow of information it will be difficult, or even impossible, to maintain control (Ashby 1956).

In this paper the controlled system consists of designers, PM and the client producing design solutions. The representation, describing what will result (costs, values) if decisions (present design solutions) will come true, is a Building Information System of component level target costing (together with the designers' CAD systems).

DECOMPOSITION OF DESIGN

To understand how designing results in cost, it is worthwhile to analyse how initially very complex conceptual design finally ends in a simple detailed manufacturing design solution.

In the beginning of design the building as a physical object cannot be predicted; there are numerous possible design solutions for any given specification. As the project progresses, more and more about the building as an object comes to be known. Design can be divided into two orthogonal perspectives (Pennanen and Koskela 2005): "Shape and Connections" and "Componets" (materials, elements…).

The design starts with solving the connections of customer's activities and massing the building in its urban environment. There are numerous possible conceptual solutions for customer's specification (and target cost), and the cost variability of possible solutions is vast. If we ask proposals from one hundred architects for a single project programming, we get one hundred different design solutions. Design as a phenomenon is similar to quantum physics. There are numerous stages existing at the same time and they are all true at the same time. And, like quantum mechanics, as we observe (manage) the phenomenon, it will "collapse" into one single stage (the drawings we finally construct).

When we deal with shape and connections, the components, like cooling beams, suspended ceilings, hollow-core slabs or external-wall systems are not under design. When we accept the concept, design starts to concentrate on determining the components and it lasts until the construction is finished. The shape-and-connections stage determines the distributions and quantities of the building elements (in a one-storey building there is more roofing structures and foundation bases than in a two-storey building but less stairs). On the other hand, component-stage determines the unit costs of those quantities. The building cost is a product of these two perspectives.

It seems that traditional estimating (measure quantities and price them) cannot produce fast economic feedback (in a week or two after concept design starts) as there is a wide temporal gap between the two orthogonal design perspectives. In the first week the external wall and slabs can be measured, but not the taps, cooling beams, partition walls. The external wall cannot be priced.

COMPONENT LEVEL TARGET COSTING

In target costing the costs should not be allocated to the components based on historical distributions of costs. Customer requirements (and buildings) tend to be unique (car parking in cellar, a store, a pub and a kindergarten in the first floor, labs in second floor and offices in third and fourth floor) and customer's requirements tend to drift during project definition (iterative process). Therefore the distributions tend to be unique (Pennanen & Ballard 2008). Using a statistical basis would also prevent learning as the origin of the costs would be stored completely in a black box.

TaKu^{TM} Building Information Model uses a constructive basis to define the distributions of the building components and uses black box modelling to fit the model to the tender-price level in the markets (Haahtela Y. 1980). TaKu^{TM} information model's input information consists of spaces needed by the client (200 m^2 library hall, 35 m^2 operating theatre…) and requirements the client sets on the spaces (internal temperature control within +- 2 degrees, 20 pneumatic outlets, 6 m height, 400 lux…). Furthermore information on constraints concerning soil and urban environment are to be added. The model yields expected life cycle cost (investment and maintenance costs) for new buildings or rehabilitation projects (the information model is mainly used in renovation projects).

The application models the building components ("reference systems") which can provide the customer requirements. The result is priced quantities of "reference systems" that exist in the market. Modeling follows Nam Suh's independence axiom (Suh 1990), "a good design is made up of design parameters that result in the independence of the functional requirements from each other".

Some examples of component level modeling: Number of luminaries is modeled by the formula <N= ExA/(FxnxUfxMf)>, where E is illumination required, A is size of the space, F is efficiency of the lamp… It is not necessary to design first a design solution to count out the number of luminaries (or size of main switchboard, or…) if we know client requirements (assembly hall 1200 m2, 600 lux), as the designers use the same formula to determine the number of luminaries. Cost then can be based on component level market data. Luminaries can be priced by unit prices of luminaries sold in the market.

Elevator modeling is based on demanded waiting times, round-trip-time and peak handling capacity. Beams, slabs, columns and foundations modeling is based on demanded ability to accommodate functional loads, demand on span without columns and on the information of the soil etc.

PROJECT LEVEL TARGET COSTING

However, component level (from bottom to top) product model does not yield accurate information concerning the total life cycle cost of the whole building project. In construction there are emergent features (Haahtela 1980, Pennanen & Ballard 2008). As a result, design cannot be managed only through components since costs are also affected by human factors in the design process, human factors in production-on-site, and market fluctuations (e.g. contractors expectations of profit right now). Many of the factors are random and chaotic. From top to bottom calibrating is needed, too.

To find a reasonable market-cost-level, adjusting has been done using a cybernetic closed loop with a black box (Beer 1966). The client requirements for the product are first modeled to expected cost, and the result is then compared to market costs, tenders. If there is a strong correlation between expected costs and tenders, the model describes well what happens when clients change their requirements. Expensive in the product model is expensive in reality. But, because of emergent reasons, there always is a difference in cost level. This difference is stored in a black box, and black box is updated once or twice a year (black box means that we do not know, or do not need to know the mechanism inside the box). The black box is adjusted so that there are several possible solutions for a design problem (set of client requirements), in the range where costs do not correlate strongly with quality (see next chapter).

DESIGN STEERING CONCEPT

STEERING RANGE

There is a big variety in design solutions. Architect Niukkanen (Niukkanen 1980) has studied the correlation of architectural quality and building costs. The population of the study was design & build competitions in Helsinki residential building production. They all are good quality in terms of measurable criteria. The architectural quality (external beauty, internal comfort, habitability) was analyzed by a delphi-group and value analysis matrix (y- axis in figure 1).

As far as costs are concerned, the possible range is shown on the x-axis. If we do not steer the design to target cost, the possible range covers all the possible design solutions that fulfill measurable requirements. Minimum cost seems to yield poor quality in terms of soft criteria. But very soon, when moving to the right from minimum to “reasonable cost” production, the correlation between quality and costs disappears. The most expensive design solution was quite poor in terms of quality and the best quality was achieved with a reasonable price (of course, high price did not prevent good quality).

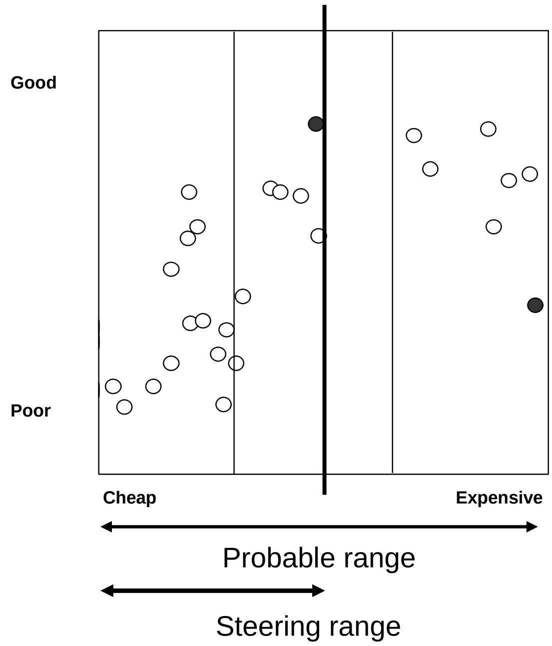

Figure 1: Correlation of Cost and Quality

If we operate in the "reasonable costs" area, then the quality cannot be assured by allocating more money to production, indeed, this may just as well lead to a poor quality solution as a high quality one. It seems that architectural quality is linked to creativity and artistry of the design group in interpreting our culture and its changes rather than to money (Pennanen 2004).

The steering range (range within the design has to be steered) can be adjusted narrower than the possible range, e.g. the variety of design solutions could be reduced, without sacrificing architectural values. In the steering range, the whole range of architectural quality can be achieved. If the target cost is placed in this area, then the cost can be considered as a fixed variable (one design criteria among the others) and the architectural quality is the variable that is managed (by steering the design). Haahtela BIM sets expected cost in the middle of the observed cost distribution (after extremes has been removed) twice a year. Project management can then decide where to set the target cost.

FEEDBACK REPRESENTATION OF THE STEERING SYSTEM; "DEFENDING CHAMPION"

In complex circumstances the steering system requires a representation that describes reality as closely as needed to provide the project management with feedback. CAD models cannot provide the designers with proper cost information (final life cycle costs if this concept design were realized) because of the cumulative nature of design (see decomposition of design). The component level target costing information model provides the designer and management with all the components and costs functionality requires, 100 % of costs already at the start of conceptual design as "one possible design solution". As there are limitless design solutions for the specification, this model is as "right" as any design proposal until "quantum mechanics collapse" into one accepted design solution.

The model can be considered the "defending champion"; to be correct until the designer proves some of the components to be in contradiction with the designer's concept. Then that part of the model is replaced by the designer's information; e.g. there is 20% more external wall in the designer's concept. The components that cannot be measured in the early stage of design will be estimated according to the model (quantity and unit costs of tabs, luminaries and windows in a model are based on the customer's need on services the components provide and we can assume that designers no not design later on more than needed). Thus the rapid estimate of design will differ from the target cost only because of designers' decisions. As the model is transparent, the designer can either change the design concept (new massing, less external walls) or gain benefit by trade-offs somewhere else (I will design the suspended ceiling for half the price of the model on floors 2 to 6). The designer can test many concepts in a short time. This can be called design strategy planning because the decisions can be detailed later (it is not necessary to define the suspended ceiling yet, it is a waste of time. The architect's commitment is enough). As the CAD model provides more information, it will be transferred to the target costing model. Dialogue with these two information models builds up a super-BIM, representation of all the components and their costs all during the design; the feedback loop for steering the design.

This kind of modelling has been tested in many projects in Finland. It has helped mutual understanding between the designers and management as far as costs and design decisions are concerned. Designers have felt that they have more power and target cost has been achieved in these projects.

ACHIEVING VALUE IN TARGET COSTING AND STEERING THE DESIGN

Cost is just half of economy. Projects aim also to provide value for the customer business. Value generating is well managed in strategic workplace planning and target costing. Strategic workplace planning (Pennanen 2004) determines the need for spaces in relation to the customer's business plan and business activities. Target costing (Pennanen & Ballard 2008) defines the life cycle costs in relation to the performance the customer requires of spaces and the building.

Both concepts operate with measurable value, with value that can be described with words and numbers in an understandable way (a meeting room for 12 people is needed, internal climate control within +/- 2 celsius, 600 lux, video monitor…).

Concern with losing this value is understandable, as steering the design seems to concentrate on costs. Target costing 'targets' both value and cost. Arto Kiviniemi has studied measurable value transfer from project definition through design to production (Kiviniemi A. 2005). Kiviniemi defines the rules how customer requirements should be included into CAD product models to ensure requirements transfer to all designers and site managers. Kiviniemi's model is in practice in Finland and Norway.

Concern for achieving architectural soft values within cost constraints is also reasonable. If we look at Figure 1, we see the very weak correlation between costs and architectural quality in the steering area; adding money does not ensure better value. In this area architectural value is rather correlated to staffing and management than money; better design and better management will yield better quality.

A CASE

The Case is Santasalo Gears Ltd Headquarters extension in Karkkila, Finland. Santasalo Gears is a worldwide supplier of mechanical drives for the process industries. The client set the target cost 5 percents below the current "best practice" cost, determined by TaKu BIM. However, the client required "exceptional impression" of architecture. The building program was a 1600 gsm extension linked to existing office (2) and factory (1).

The Architect (Prof. Kai Wartiainen) made the first proposal. It consisted of two masses. A two storey narrow mass (4) was connected to an existing oval- shaped office-mass (2) by one-storey mass (3) that formed a kind of bridge between the existing one-storey roof-terrace and two- storey office (figure 2).

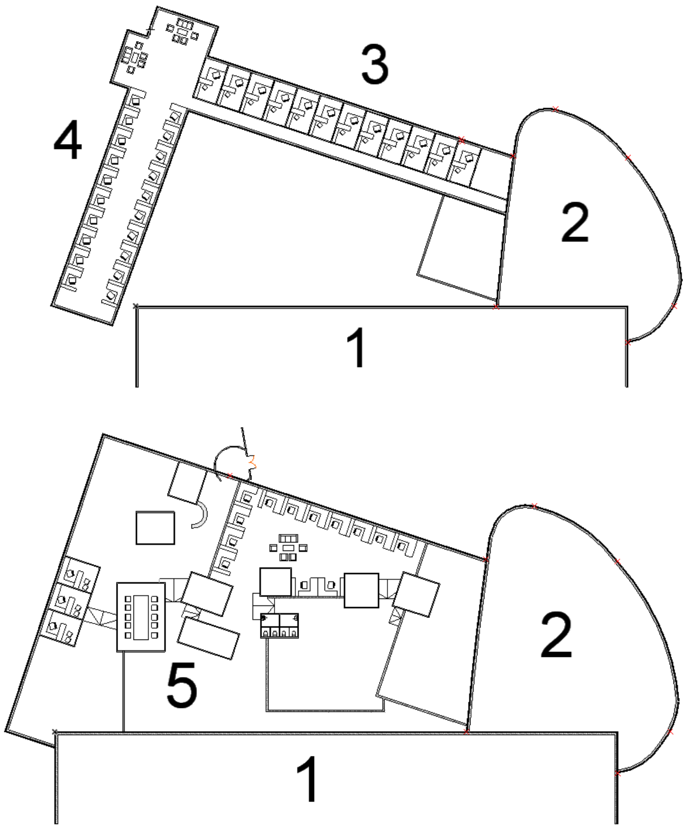

Figure 2: The first sketch proposal (left) and the sketch that led to realization (right).

The external walls, foundation structures and roofing structures were measured and all the other quantities and unit costs (other structures, hvac-systems) were modelled by the TaKu BIM. The feedback representation, "defending champion" corrected by measured information, indicated that the proposed mass would require very cheap detailing and materials. Narrow masses have relatively greater quantity of external walls and foundation structures. The corridor serving only to one side increased the amount of slabs, roofing structures and finishing.

The architect was not satisfied with future options; elegant, a little bit conventional mass with cheap finishing. He created totally new design strategy; economical massing, cheap materials and very expensive detailing (Wartiainen & Pennanen 1996). He called it "jeans-style"; you can use economical materials and still manifest chic design (when your budget is low).

The new proposal (one-storey mass) required only two external walls, as the mass was also bordered by the existing office (2) and factory (1). The landscape offices, 100 – 150 sqm by size, were formed by terraces, 80 cm height difference from one to another. Two coordinate systems were used; factory coordinates and 18 degrees skewed. The way from out-door to existing office (2) goes upward through cabins in different coordinate systems like a path in a Provencal village. Roofing beams were bent using two coordinate systems to create an undefined geometric form of ceiling. Materials were defined to be very cheap; concrete blocks, no suspended ceilings, etc. The cost of the proposal was modelled by BIM, and found to be promising. Besides designers, also subcontractors were engaged to find solutions (component level design-and-build) for achieving target cost (new technical innovations, tested components in a university lab, one registered trademark owned now by the steel contractor). It led finally to the target cost.

The case proved that it is possible, with the help of BIM, to define a design strategy in the very early phase for shape-and-connections and components at the same time, within the target cost. This case received a Steel Construction of the Year Award (1996) in Finland, proving that it is possible to gain good quality, as well.

CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

The building information cost model has been in commercial use in Finland for more than ten years with good results (Whelton 2004). Component level target costing has been in use as well, but the application is not sufficiently transparent for designers to use without interpretation by project managers and estimators. With these limits, the concept of steering the design has been in use in Finland for more than five years, also with good results. Because of the limitations of the building information model, very skilful people are still needed and it has been a big task to educate conventional project managers to systematic steering of design.

Future research is needed to explore the application of this type of cost modeling to other geographic and industry domains. Future research is also needed to develop information modeling more transparent so that designers could use that in parallel with CAD models.

Future research is also needed to compare different approaches to designing-to-targets, including the possibility of blending elements from the different approaches into a more powerful hybrid methodology. That methodology might, for example, combine Haahtela's target costing BIM with such design management tools as set based design, A3 reports, and the Choosing by Advantages method.

More research is needed from the designers' point of view, how they see value generation under target costing management of design. When target costing was implemented in Finland in the 1980's, when contradictions occurred, architects felt that their design was "right" and target costing was wrong. Today most Finnish architects want well analysed target cost before starting to design.

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