Concept of a Holistic, Life-Cycle Oriented Yield, Cost Planning and Controlling Process Model

Magdalena Proyer[1], Gerhard Girmscheid[2]

Abstract

In times where high competition, low profit margins, tight time project schedules and cost overruns dominate the construction industry, life-cycle oriented design as well as holistic yield and cost planning in combination with controlling processes are the crucial factors for project success. Project modifications often cause cost overruns and a decrease in yield during late design stages and construction. This is due to the fact that in the early design phases, where the project strategy is developed and modifications can still be carried out with low effect on the actual costs and the actual schedule, project targets and building requirements are not yet clearly defined. This paper presents the concept of a holistic, life-cycle oriented yield, cost planning and controlling process model, targeting the planning process of building projects. The model is built on a mathematical basis covering all project phases, where life-cycle oriented income, cost and yield planning is adjusted according to the system standard, the system targets and requirements by means of multi-criteria system optimization. The holistic, life-cycle oriented yield, cost planning and controlling process model is directly interfaced with the customer targets and system requirements to enable a sustainable financial success of the project in all planning phases, while supporting the decision makers in deciding between "must have" and "nice to have". At each project phase, following procedures are carried out: the determination of system requirements and integration into the system, the life-cycle oriented estimation of income, costs and hence the net present value and yield, a system optimization by multi-criteria decision analysis and a target check. A holistic and cybernetic approach allows the controlling of life-cycle costs, yield and target accomplishment, at each project phase, as well as the application of steering measures in case of deviations. The holistic, life-cycle oriented yield, cost planning and controlling process model is an important support tool for decision-making, within a life-cycle oriented approach. The model enables the determination of sustainable system requirements as well as cost planning, reporting and controlling, through all stages of the project with a continuous system optimization.

Keywords: construction management, life-cycle cost planning, cost controlling, requirements-engineering, multi-criteria system optimization.

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[1] Scientific Assistant and Doctoral Student; Institute of Construction and Infrastructure Management; ETH Zurich; Wolfgang-Pauli-Strasse 15, CH-8093 Zurich ; proyer@ibi.baug.ethz.ch.

[2] Professor; Institute of Construction and Infrastructure Management; ETH Zurich; Wolfgang-Pauli-Strasse 15, CH-8093 Zurich; girmscheid@ibi.baug.ethz.ch.

1. Introduction

Today’s construction practice is characterized by continuous cost overruns, time and time again. Frequently, investment targets, initially defined by the client, are continuously exceeded during the planning and construction process. In many cases, the influence or rather the endangerment on the project’s outcome and yield isn’t analyzed and considered early on. This can be observed not only in small projects, but also in large-scale projects in the private as well as in the public sector. Particularly, when concerning large-scale projects, although there may be a high concentration of specialists working on those projects, cost overruns are all too common. Nevertheless, there are professional clients and project managers, who have the means next to the formal and intuitive ability to manage projects, according to a target oriented cost controlling process.

Looking into the field of construction management research, there aren’t any holistic and cybernetic concepts for the yield and cost controlling process, which control the investment costs through the whole planning and construction process, based on a life-cycle oriented income, yield and cost prediction, in accordance with a well-grounded requirements engineering. Considering the above in conjunction with the current situation in construction practice, there is a high potential for system requirements optimization, interactive cost optimization and cost controlling, regarding the building’s system requirements based on the customer targets for all stages of planning and construction.

Taking up this issue, the concept of a holistic, life-cycle oriented yield, cost planning and controlling process model (LYCPC-model) will be presented in this paper. The LYCPC-model uses the methodology of multi-criteria decision analysis to evaluate qualitative and quantitative criteria at each phase of the project, allowing the project planner to control the system requirements, based on the customer targets, and costs by making corrections, if necessary. Using the approach of the LYCPC-model, costs and system requirements of a building project can be optimized ensuring a successful investment and a predefined yield.

2. Life-cycle oriented cost planning and requirements engineering

A well-grounded life-cycle oriented cost planning and cost controlling has to be implemented right at the beginning of a project and has to be pursued systematically with adequate tools for each project stage. Girmscheid & Motzko (2007c) describe the cost planning and controlling process very detailed for Switzerland and Germany, including a detailed cost calculation. In practice, there are clear structure systems to build upon a mathematically oriented cost controlling process model. These are often published in national standards. In Switzerland for example, the Swiss Center for Rationalization in Construction CRB (2009) provides standards, which enable a systematic and hierarchic classification and a stepwise subcategorization of construction costs in the planning process. The published standards also comprehend corresponding cost values from reference projects. In Germany, the construction cost information center of the German architects' chambers BKI (2012) releases a comprehensive collection of statistic cost values for buildings, building elements and positions with the correlating cost structure. Meyer-Meierling (2010) describes the tasks and levels of cost planning according to the Swiss project phases [SIA (2001)]. Girmscheid

(2007a; 2007b) proposes a cost model with a project phase related procedure and the implementation of life-cycle costs. The model controls the fulfillment of the customer stipulated targets with regard to the system requirements and the investment costs as a function of the life-cycle oriented yield.

A life-cycle oriented yield and cost approach is becoming more and more important. This is largely due to the efforts in more energy efficient building practice and a correlated reduction of energy costs. In a calculation model, Pelzeter (2006) describes the influence of geographic location, design and environmental aspects on the paying structure during the life cycle of a building. In correlation with a life-cycle oriented approach for the reduction of energy costs, Weizsäcker et al. (2009) mention that a shifting of the planning process to earlier project stages is crucial for a successful project outcome. Girmscheid (2010a; 2010b) has widened the approach to monitor and actively control the customer targets at each design stage by developing the system requirements interactively with the cost budgets of the customer, with regard to the life-cycle return on investment. The LYCPC-model is built on the target and system requirements process model [Girmscheid (2010a; 2010b) and Krönert (2010)], which implicates an early definition of targets as well as requirements and therefore an integration of the requirements-engineering process into the planning process of construction projects. The LYCPC-model ensures that the minimum system standard will always be targeted in case of cost correction due to overruns, to secure the attractiveness of the target rent. Additionally, during the advanced detailing of the planning, it enables the decision maker to differentiate between nice to have and must have, in case of divergence between system standard and target cost. Due to this holistic approach the LYCPC-model differs from pure target cost control.

3. Research Methodology

The Research Methodology of the presented holistic, life-cycle oriented yield, cost planning and controlling process model is based upon the hermeneutic research approach according to Girmscheid (2007d). Building on Popper's "Three-World-Theory" [Popper (2002)], the construction management sciences have to be classified as world three, products of the human mind. Constructivism [Glasersfeld et al. (2007)] is used for the development of the theory and logic driven deductive model. System theory according to Bertalanffy (1973), cybernetics according to Ashby (1971) and Wiener (1991), and methods from operations research [Winston (2004)] build the theoretical reference framework.

The holistic, life-cycle oriented yield, cost planning and controlling process model is developed in a generic, logic driven and deductive way, over the life-cycle phases of construction projects. Its structure is theory-driven and based on a mathematical approach. The system theoretic modeling concept consists of

- the project phases,
- a cybernetic requirements management,
- a life-cycle oriented approach to income, yield and cost planning and
- a multi-criteria system optimization.

Besides the system theoretic modeling and demarcation of the contents, a dynamic and iterative controlling mechanism is carried out, in form of control circuits. This cybernetic process is repeated at all phases of the project and provides target oriented balance and steering between the intended value, the benefit and costs.

4. Concept of the holistic, life-cycle oriented yield, cost planning and controlling process model (LYCPC-model)

The concept of the holistic, life-cycle oriented yield, cost planning and controlling process model enables project developers/planners/managers, total service contractors, system providers and so forth, to counsel the client in all his decisions, with a clear, transparent and holistic yield and cost steering process. This includes the identification of consequences regarding the yield as a function of the required system standard (requirements), to achieve a sustainable yield and related investment costs. In particular, necessary requirement modifications have to be distinguished in reference to the yield, effecting the whole life cycle of a building.

4.1 Cybernetic cost controlling and its effect on cost compliance

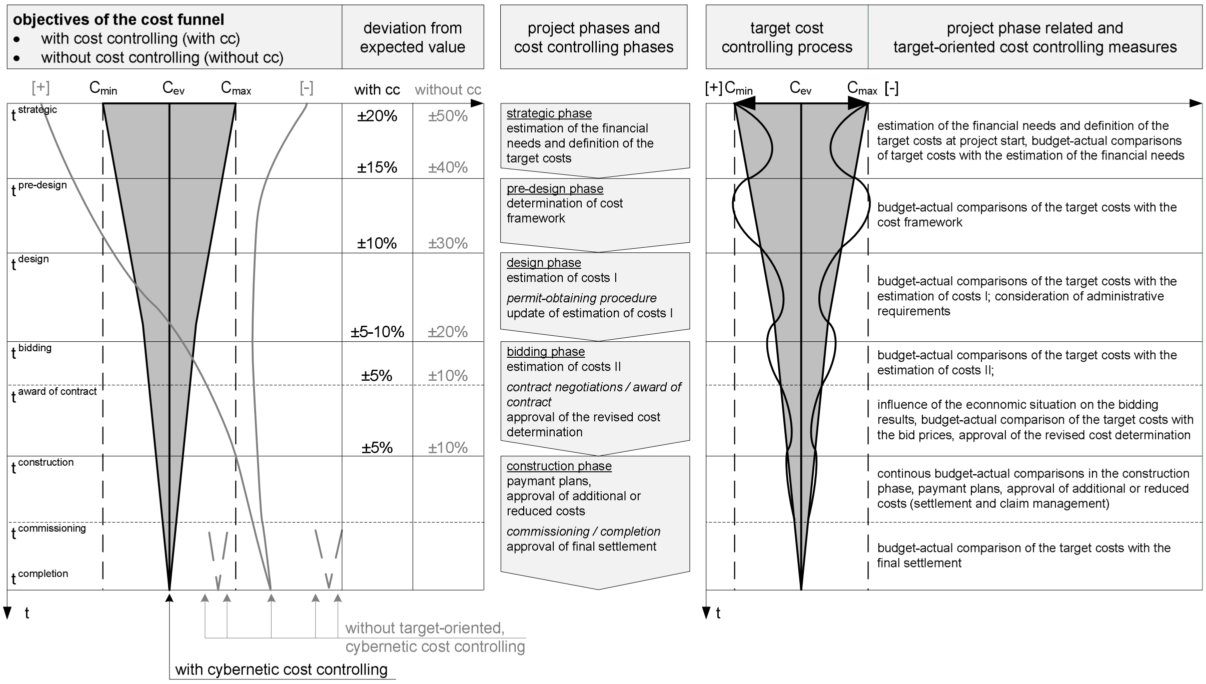

Figure 1: Cybernetic cost controlling and its effect on cost compliance according to the project phases [referring to Girmscheid (2007a)]

Figure 1 shows the effect of target-oriented and holistic yield and cost controlling on cost compliance, according to the various project phases. The cybernetic procedure, which contains control circuits (budget-actual comparisons) at each project phase, guarantees that deviations from the cost target and their triggering causes can be detected in good time. Especially in early project stages, the decision bandwidth is still broad. This gives the client, respectively the project manager, the option to develop the project in accordance with the target cost margin and requirements. According to the cost funnel (figure 1) the influence possibilities on the development of costs, according to the system standard, become smaller with the project's progress, where major changes cause additional costs.

4.2 System theoretic structure of the LYCPC-model

In order to provide an adequate and clear application in practice, according to project progress, the holistic, life-cycle oriented yield, cost planning and controlling process model (figure 3) is composed of two process levels:

- the primary project developing process and
- the LYCPC module processes.

The primary project developing process describes the model over the course of time and consists of the different project phases, namely strategic phase, pre-design phase, design phase, bidding phase, construction phase and operation phase. They allow for a holistic and cybernetic connection over time. Hence for each of them, a milestone, which contains specific targets concerning costs, time, quality and so forth, must be achieved, in order to progress to the next project phase. In this primary project developing process, the LYCPC module processes are embedded. They are linked with each other, so that each LYCPC module process requires the output of the previous one, while providing the input for the following one. The linkage and dependencies mentioned above provide a structured procedure during the primary project developing process, i.e. during all the project phases.

The LYCPC module processes (figure 2) are either assigned to the target oriented planning phase, which includes requirements-engineering, estimation of income, costs and yield, or to the controlling and steering oriented planning phase, which comprises multi-criteria system optimization and a target check.

LYCPC MODULE PROCESSES	PHASES
• determination of system requirements and integration into the system, • prediction and estimation of income, • prediction and estimation of costs, • estimation of the net present value and the yield,	target oriented planning phase
• system optimization by multi-criteria decision analysis and • target check.	controlling and steering oriented planning phase

Figure 2: LYCPC module processes

In figure 3, the holistic, life-cycle oriented yield, cost planning and controlling process model is shown with the detailed primary project developing process and the detailed LYCPC module processes.

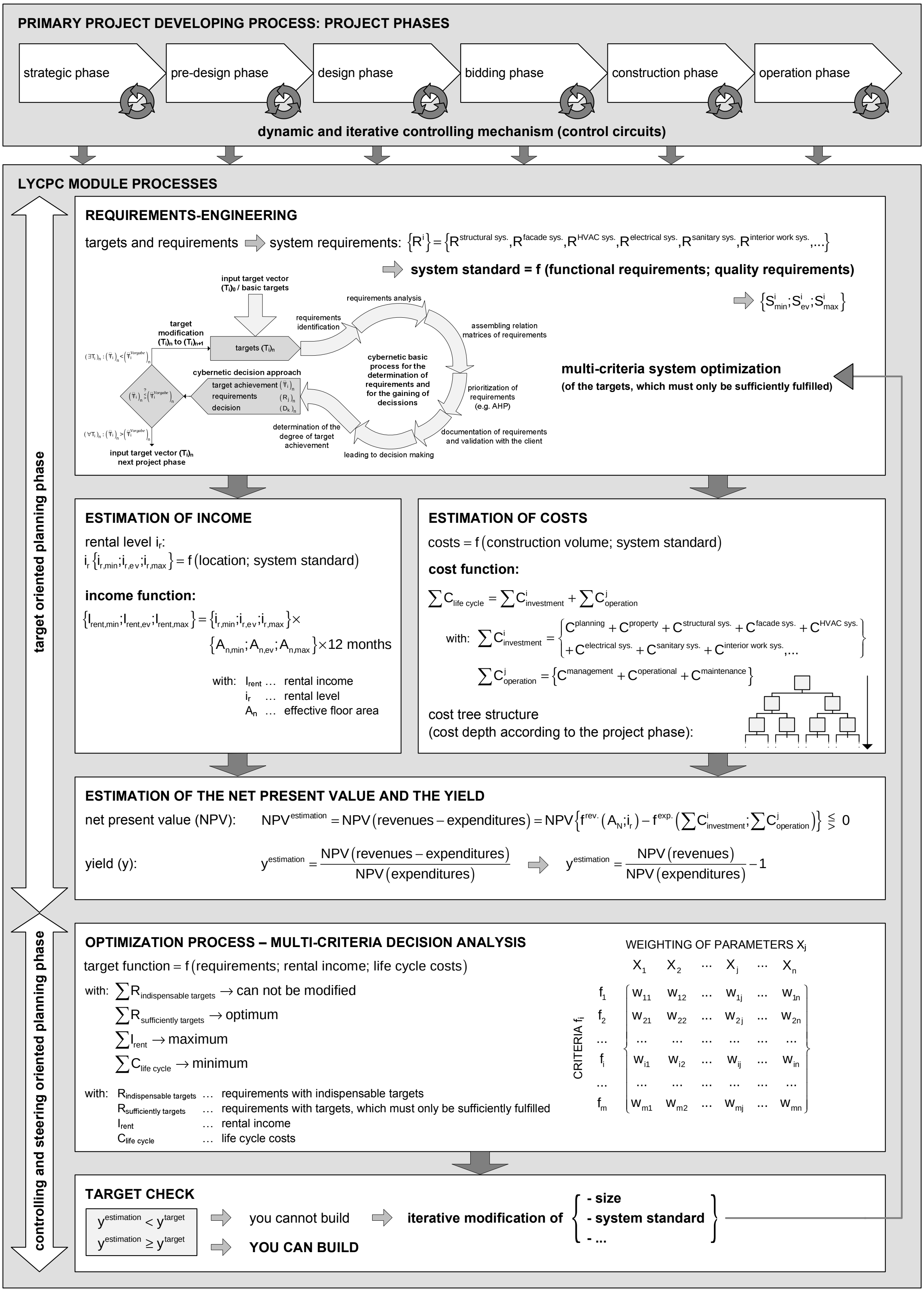

Figure 3: Holistic, life-cycle oriented yield, cost planning and controlling process model (LYCPC-model)

4.3 Contents and procedure of the LYCPC-model

In the strategic planning process, the client or rather the project manager has to define the project portfolio, including geographic location and project type, as well as the target yield. Based on these criteria, a target level is defined and compared to an ascertained market demand. The investigation results must be evaluated and positive development potential needs to be identified. This constitutes the basis for adequate property acquisition. Furthermore, the system standard and the rental level for the potentially to be developed property, result from the geographical location of the property, the life-cycle oriented attractiveness for the user and the segment of demand.

Already at this project stage, targets and requirements have to be defined with a generic and axiomatic requirements-engineering. Girmscheid (2010a; 2010b) defines and differentiates between user requirements, client or investor requirements, environmental requirements, site and building-ground requirements, regulatory requirements (standards and laws), design requirements and construction requirements. Having obtained them, they have to be transferred into system requirements $\left(R^{i}\right)$:

$\left\{R^{i}\right\} = \left\{R^{\text{structural sys.}}, R^{\text{facade sys.}}, R^{\text{HVAC sys.}}, R^{\text{electrical sys.}}, R^{\text{sanitary sys.}}, R^{\text{interior work sys.}}, ...\right\}$.

These are classified into functional requirements and quality requirements, for instance architectural, technical, HVAC (heating, ventilation and air conditioning) and finishing quality, which consequently determine the system standard. Thereby, it is important to note that the system standard fluctuates in a certain range:

system standard = f (functional requirements; quality requirements) → $\left\{S^{i}_{min}; S^{i}_{ev}; S^{i}_{max}\right\}$.

To obtain a sustainable requirements-engineering, the target achievement $\left(T_{i}\right)$, the requirements $\left(R_{j}\right)$ and the decisions $\left(D_{k}\right)$ have to be determined and verified in a cybernetic requirements-engineering development process at each project phase. [compare Girmscheid (2010a; 2010b)]

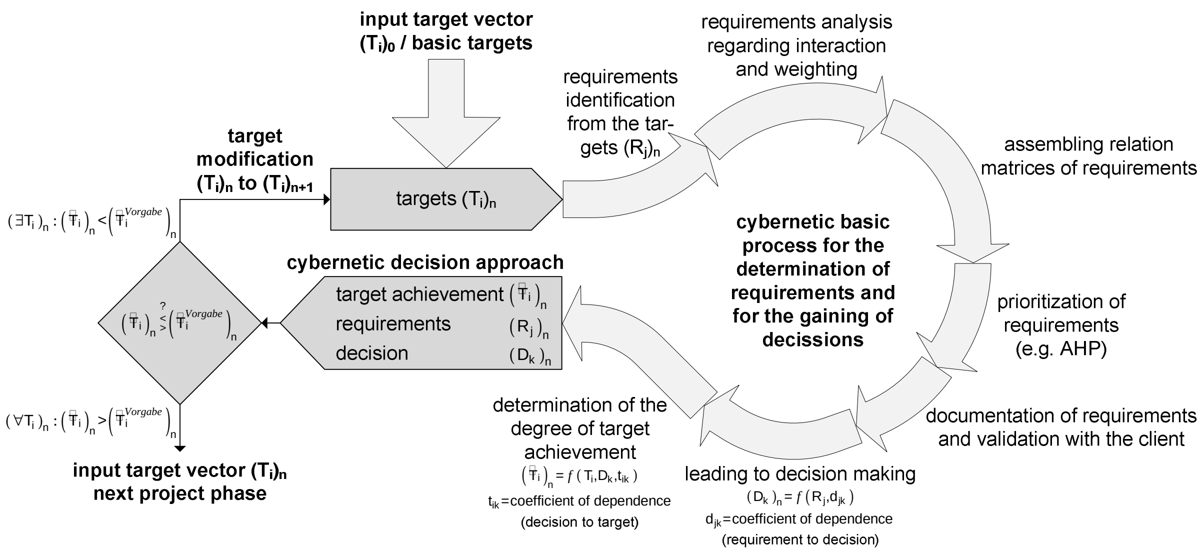

Figure 4: Module process "requirements-engineering" [referring to Girmscheid (2010b) and Krönert (2010)]

In the next step, building on the system standard and the geographical location of the building project, the rental level (i_r) can be assessed and the future rental income predicted, at the time of observation:

$$i_r \{i_{r,min}; i_{r,ev}; i_{r,max}\} = f(\text{location; system standard}).$$

Much in the same way as the rental level, the size of the effective floor area (A_n) can fluctuate in a certain range, corresponding to the range of the defined system standard. Hence the rental income per year (I_{rent}) can be calculated:

$$\{I_{rent,min}; I_{rent,ev}; I_{rent,max}\} = \{i_{r,min}; i_{r,ev}; i_{r,max}\} \times \{A_{n,min}; A_{n,ev}; A_{n,max}\} \times 12\,\text{months}.$$

Utilizing these interval approaches, the client and project manager gain the decision spectrum, in which target-oriented decisions can be made, implementing a cybernetic controlling process.

For the calculation of the net present value, concerning the life cycle of the building and hence the yield, costs for the construction phase $(C^{i}_{investment})$ as well as for the operation phase $(C^{j}_{operation})$ need to be calculated. The cost prediction is, similarly to the income prediction, bound to some uncertainties and moves within a certain range. The client and project manager must realize that the cost values for cost calculation need to be adapted to the system standard of the building and subsequently multiplied with the exact quantities:

$$\text{costs} = f(\text{construction volume; system standard}).$$

The life-cycle oriented cost calculation contains the calculation of investment costs for the construction phase and operation costs for the operation phase:

$$\sum C_{\text{life cycle}} = \sum C^{i}_{investment} + \sum C^{j}_{operation}.$$

Looking at the calculation of investment costs, the cost structure follows the structure of the building system and can be arranged as follows:

$$\sum C^{i}_{investment} = \left\{ \begin{matrix} C^{\text{planning}} + C^{\text{property}} + C^{\text{structural sys.}} + C^{\text{facade sys.}} + C^{\text{HVAC sys.}} \\ + C^{\text{electrical sys.}} + C^{\text{sanitary sys.}} + C^{\text{interior work sys.}}, \ldots \end{matrix} \right\}.$$

Quantities of the different construction units need to be determined and then multiplied with cost values obtained from reference projects. While doing so, it is essential to investigate cost values according to the system standard and geographic location of the project in order to achieve meaningful results. When calculating the investment costs in the LYCPC-model, a cost tree structure according to the building system has to be followed, in order to support a holistic and cybernetic project progression. This allows cost tracking at every project stage and in case of deviations, the identification and analysis of cause and effect. With the mentioned holistic and cybernetic approach, cost deviations are detected early and consequently regulatory measures can be initiated accordingly. The cost tree structure for the calculation of an exterior wall, as well as the correlation between cost depth and project phase, is shown in figure 5.

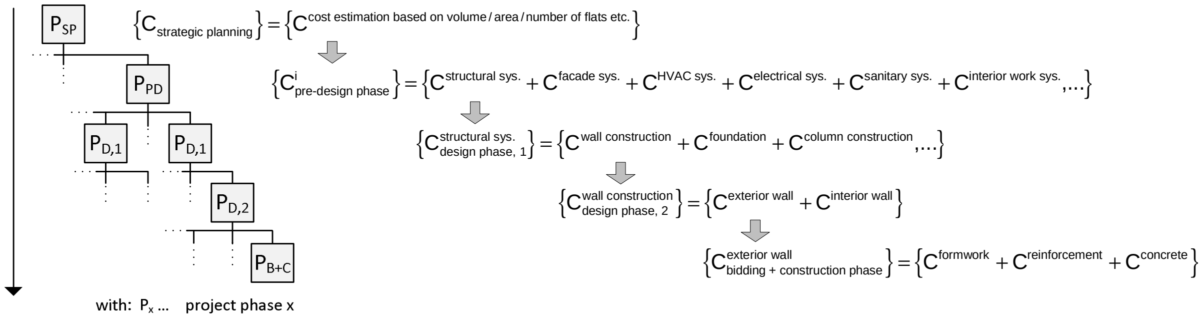

Figure 5: Cost calculation according to a tree structure

In a further step the costs for the operation phase $\left(C^{j}_{\text{operation}}\right)$ have to be calculated. They contain management costs, operational costs and maintenance costs and have to be discounted to the time of observation:

$$\sum C^{j}_{\text{operation}} = \left\{C^{\text{management}} + C^{\text{operational}} + C^{\text{maintenance}}\right\}.$$

Management costs (for example costs for administration) and operational costs (for example costs for cleaning) arise continuously. Additionally to these, costs for maintenance incur at different points of time. They include costs for smaller measures, which recur in certain time intervals like painting walls, window frames and doors or sanding parquet floors, and costs for significant measures like the renewal of the roof, the windows or the heating installation. Significant measures should be carried out at the same time in order to realize possibilities for a system optimization, to use synergy effects and consequently to achieve cost reductions.

Based on the results from the life-cycle oriented income and cost prediction, the net present value can be estimated by discounting the predicted costs and the predicted income to the time of observation.

$$\begin{aligned} NPV^{\text{estimation}} &= NPV(\text{revenues} - \text{expenditures}) \\ &= NPV\left\{f^{\text{rev.}}\left(A_N; i_r\right) - f^{\text{exp.}}\left(\sum C^{i}_{\text{investment}}; \sum C^{j}_{\text{operation}}\right)\right\} \ \begin{matrix} \leq \\ > \end{matrix} \ 0 \end{aligned}$$

If the estimated net present value $\left(NPV^{\text{estimation}}\right)$ is higher than zero, the yield $\left(y^{\text{estimation}}\right)$ can be calculated:

$$y^{\text{estimation}} = \frac{NPV(\text{revenues} - \text{expenditures})}{NPV(\text{expenditures})} \longrightarrow y^{\text{estimation}} = \frac{NPV(\text{revenues})}{NPV(\text{expenditures})} - 1$$

Having obtained these results, the system can be optimized by using the methodology of multi-criteria decision analysis. While doing so, the project targets, especially the indispensable targets (for example the defined yield) must be achieved. The application of multi-criteria decision analysis into the planning process of a building project offers new possibilities to optimize qualitative as well as quantitative criteria, while a certain cost margin can be assured. The system can be optimized for instance either by using other materials, changing the floor plan or by making changes in the architecture. In case of cost deviations, the targets, which must only be sufficiently fulfilled, need to be modified and optimized in order to reach the indispensable targets, such as a certain yield or a defined system standard. The existing influencing opportunities, utilized for controlling the system standard and the cost development, are identified and then formulated mathematically using functional dependences. Hence, possibilities for design and action including their effect over the life-cycle of a building are shown, beginning in the strategic phase up to operation. The process of a cybernetic controlling process model is provided by control and iteration circuits, which ensure target control by considering higher level information pertaining to the progress of the project.

As mentioned above, the cybernetic procedure of the model demands a target check before advancing into the next project phase. Therefore, if the calculated yield is higher than or equal to the target yield of the customer $\left(y^{\text{estimation}} \geq y^{\text{target}}\right)$, the project can be carried out successfully, which means passing on to the next project phase. If the calculated yield is lower than the initially target yield of the customer $\left(y^{\text{estimation}} < y^{\text{target}}\right)$, the project cannot be carried out successfully and consequently, a system optimization must be conducted alongside a repetition of all LYCPC module processes. The process repetition must be carried out until the yield is higher than or equal to the initially determined yield $\left(y^{\text{estimation}} \geq y^{\text{target}}\right)$ in order to ensure the client or rather investor a sustainably successful investment. Otherwise, the project must be terminated or retargeted.

By following the above described module processes during all phases of project, the project manager can build upon a solid basis. The LYCPC-model enables the identification and implementation of requirements at early design phases, so as to optimize the correlation with the cost and income side. In combination with a holistic controlling process, the model ensures the detection of target deviations in good time and offers the option to initiate steering measures.

5. Conclusion and outlook

This paper has presented the concept of the holistic, life-cycle oriented yield, cost planning and controlling process model (LYCPC-model), a new holistic approach to cost management and requirements engineering. A major good of the model is to optimize the relation between the requirements of a building and its investment and maintenance costs to achieve a specified yield. Based on the holistic, cybernetic cost controlling process model [Girmscheid (2007a; 2007b)] and the target and system requirements process model [Girmscheid (2010a; 2010b) and Krönert (2010)], the LYCPC-model consolidates cost planning and requirements-engineering by means of optimization methods. The LYCPC module processes, as described in this paper, will be developed in further detail. Thereby, the focus will be laid on the optimization process. For this purpose, the methodology of multi-criteria decision analysis will be used, as it allows the consideration of quantitative and qualitative criteria at the same time. Furthermore, the linkage, dependencies and interaction among the LYCPC module processes will be discussed, as, for example, a modification of requirements always causes cost changes. The presented concept of a holistic, life-cycle oriented yield, cost planning and controlling process model is an important step concerning target achievement and cost control, especially when considering the realization of large-scale building projects. The model enables cost controlling during all project phases and the identification of cost or quality divergences at early stages and makes timely steering measures possible.

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