Life cycle management methods in practice

A literature study towards the benefits and complications of life cycle costing (LCC)

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Samenvatting

Life cycle costing is een veelbelovende methode om de impact van een afweging en keuze in kosten uit te drukken. Tegenwoordig speelt het milieu een steeds belangrijkere rol in ons dagelijks leven. Van besluitvormers wordt daarom verwacht dat zij keuzes maken waarbij de kosten en de effecten op de omgeving en op het milieu worden geminimaliseerd. *Life cycle costing* (LCC) kent zijn oorsprong in de jaren zestig en is een methode waarbij een keuze wordt gemaakt op basis van de kosten over de gehele levenscyclus van product of project, in plaats van een keuze gebaseerd op de initiële kosten. Dit leidt vaak tot besparingen en tot een hogere kosteneffectiviteit van het project. Ondanks dat deze methode veelbelovend en voor de hand liggend klinkt, worden besluiten nog steeds vaak op basis van de initiële kosten gemaakt.

Een literatuurstudie is uitgevoerd naar de onderdelen en eigenschappen van Life Cycle Management (LCM) en de levenscyclusgedachte. De studie beoogt meer inzicht te geven in de succesfactoren en problemen van LCC, door naar literatuur en naar de uitwerking van LCC studies te kijken.

Aan de hand van deze studie kan gesteld worden dat LCC een waardevolle methode is om verschillende alternatieven met elkaar de kunnen vergelijken. LCC dwingt de besluitvormer verder te kijken dan de initiële kosten, door ook de operationele en onderhoudskosten mee te nemen in de afweging. Het is echter niet gemakkelijk om de LCC methode daadwerkelijk te gebruiken. De methode kan lastig omgaan met onzekerheden en risico's rondom besluiten op de lange termijn. Aanvullend daarop heeft LCC veel data en informatie nodig, wat vaak niet of beperkt beschikbaar is, waardoor de meerwaarde van de uitkomsten vaak beperkt zijn. Ook door besluitvormers wordt LCC vaak maar in beperkte mate gebruikt, omdat de langetermijnuitkomsten niet altijd binnen de bestuurlijke omgeving passen.

Aanvullend onderzoek is nodig om na te denken over een 'juiste' toepassing van LCC. Het is gewenst om na te denken over een LCC methode die gebaseerd is op de ervaringen en gesprekken met personen die de LCC studies uitvoeren en de besluitvormers die de uitkomsten toepassen. Een 'juiste' toepassing dient om te gaan met flexibiliteit, onzekerheden en risico's en helpt besluitvormers te kijken naar de kosten over de totale levenscyclus. De methode dient beter begrijpelijk en inzichtelijk te zijn, om de verduurzaming van onze samenleving verder te kunnen realiseren.

1. Introduction

Increased complexity has played a major role in infrastructural projects over the last few decades. The interfaces between the development phases cause risks, as different parties are responsible for design, construction or maintenance (Nuzzo, Iannopollo et al., 2014). This increased complexity is difficult to tackle with traditional project management, as parties maximize their own profit instead of increasing the quality and costs of the project as a whole. In order to deal with those risks and moral hazards that is caused by technical complexity and structure of the contracts, there is a trend moving towards life cycle management approach. As an example, the Dutch government uses integral DBFM(O) contracting structures. DBFM(O) contracting structures puts the phases of design (D), built (B), finance (F), maintenance (M) (and sometimes operations (O)) together in one contract (Klijn, 2009). One party is responsible for several or all phases of the project. This leads to more sustainable decisions over the lifetime of the project, as both initial costs and maintenance costs are considered, resulting in lower total costs of a project (Lenferink, Tillema et al., 2013).

Life cycle management contracts are used in many infrastructural projects nowadays. For example, DBFM(O) contracts are applied in road, bridge, building and tunnel projects. Its usefulness is proven in many business cases (Lenferink, Tillema et al., 2013). This results in contractors applying integral contracts standardly, where alternative contracts might be more suitable for the complexity of the project. The cost-effectiveness of a DBFM(O) contract or a split up contract alternative can be analysed using life cycle costing (LCC). This method compares project alternatives from an economic perspective (Norris, 2001). LCC gives policy makers a valuable instrument to decide whether to use an integral contract, or to tender the project into different pieces.

The life cycle costing method can give insights in understanding the conditions when to use what contracting strategy. For example, projects with complex software or maintenance systems might be more likely to be successful when put together on a systems level. The cost-effectiveness of both project alternatives can be analysed and compared under different conditions with the life cycle cost method. This paper aims to provide more insight into the life cycle management approach and best practices from projects where the life cycle cost method is applied. The impact of initial costs compared to maintenance and operational costs can be helpful in the decision making process. Success factors and complications of the LCC are considered. Based on these practical insights, future research is proposed that might lead to higher sustainability and decisions for higher cost-effective projects.

The article, based on the information retrieved from a literature review, consists of several sections. We will first take a look at the research method that was used to retrieve the necessary information on which the literature review is founded. Secondly, we will look at the life cycle management approach and how this comes in practice in integrated contracts in the Netherlands. The fifth section explains LCC, considering other methods. To gain more insights in the elements that make the LCC useful and applicable, the quantitative aspects and its pros and cons are discussed in the fifth section. The sixth section discusses examples from cases where this life cycle approach is used. Section seven analyses the interpretation and use of the outcomes of LCC by decision makers. The conclusion and follow up section consists of an enumeration of the advantages and disadvantages of LCC. Additionally, it aims to give a critical reflection and comes up with further research that is necessary to improve the method of LCC.

2. Research method

A literature review is conducted to gain more insight into the existence of life cycle management approaches. It is aimed to specifically look for literature about life cycle costing. Combinations of key words such as *integral contracts, DBMF, life cycle management, LCM, life cycle cost, LCC, maintenance, case, practice,* etc. is used to find useful and interesting articles. The article of Gluch and Baumann (2004) examines several examples of LCC projects, that lead to useful sources for this literature review. This so-called *snowballing* method is also with the references of regularly cited articles to provide a reference list with articles that are used and accepted by other authors.

3. Life cycle management (LCM) approach

Life cycle management (LCM) is an approach that analyses the sustainability of the project, product or asset as a whole. LCM have become more popular lately, as sustainability and environmental effects play an increasing role within corporations and society (Hoogmartens, Van Passel et al., 2014). While many decision makers decide on the initial costs, this does not give the most sustainable outcome for the total project in many situations (Tysseland, 2008). Westkämper, Alting et al. (2000) see LCM as a 'precondition for a sustainable development', by maximizing the ecological and economical efficiency of the project. LCM aims to minimize costs, maximize benefits of the life cycle of the project, with a minimal ecological impact and maximize performance. It is therefore a helpful tool for decisions on maintenance policy and the concerning budget and funding (Zen, 2003).

A more competitive way of thinking and the necessity of obtaining enough finance for projects, resulted in the trend towards long-term contracts (Kann, 2009; Pietroforte & Miller, 2002). In the 1990s a shift occurred towards a more competitive oriented role of the government. Due to privatization, tasks were transferred from public to private bodies (England and Ward, 2007). Before the 1990s, separated contracts of sub-parts were not adjusted to the complete project and often resulted in malfunctions and sub-optimization (Dorée, 2001). By integrating contracts that last 25-30 years, developers are stimulated to think about maintenance costs during the design of the project (Lenferink, Tillema et al., 2013). Nowadays, projects are more and more operated based on integrated contracts. The Dutch government sees integrated DBFM(O) contracts as a life cycle approach to mitigate risks and as an incentive to realize the project under lower total costs. Furthermore, it aims to decrease environmental impacts as operation and maintenance is more efficient over the total life time of the project (Rijksgebouwendienst, 2012). Success factors of the DBMF(O) contracts focus on value for money, consistent policy, sufficient amount of projects and standardization of projects (Rijksoverheid, 2015).

However, there are drawbacks in the contracting structure. First, companies often work in consortia in order to use each other's specialization. This consortium adds value for the client and makes it more likely for the companies to win the tender. However, different parties that are working in the consortium have different interests. This leads to discussions and conflicts that undermine the added value (Heuckelum, FaviÈ et al., 2007). Second, there is little flexibility in the finance structure when changes in planning occur, as the contract itself is complex. According to Verweij (2014) this leads to little governmental power to influence the process. It happens that the government does not exactly get what they requested and expected. A third and last disadvantage is that a lack of redundancy might have a negative impact on quality and transparence, as all tasks are analyzed and evaluated from the perspective of one party.

Integral DBMF(O) contracts of the Dutch government show similarities with the LCM approach, as both consider the life cycle of the project. However, life cycle management goes beyond the contract as it involves the end and demolishing phase in the life cycle phases. This is because LCM is often applied with products and assets (Gmelin & Seuring, 2014). It follows that LCM has the goal to increase sustainability in terms of environmental effects during the decision making process. DBFM(O) contracts are initiated from the idea to lower costs in large and complex projects.

4. Life cycle costing

Both life cycle management and DBFM(O) contracts aim to achieve the maximum quality or performance of the project or product over its lifetime. The costs of the quality and performances are expressed in social performance or economic performance. Sustainability can be expressed in three pillars, social equity, economic efficiency and environmental performance (Klöpffer & Ciroth, 2011; Labuschagne & Brent, 2005). Life cycle assessment (LCA) measures environmental performance, where LCC measures the economic efficiency.

Life cycle analysis (LCA) is an environmental tool and is often used together with LCC, as environmental assessment needs to be expressed in the social and economic costs (Kloepffer, 2008). LCA compares the environmental performance of alternatives from an environmental and societal perspective. The impact is expressed as the total material flows on the product, from design to disposal expressed in units of mass and energy.

Hoogmartens, Van Passel et al. (2014) developed a framework (figure 1) that shows the integration between the different sustainability assessment tools. Cost benefit analysis (CBA) is not directly a life cycle instrument, but can be considered a sustainability tool when external costs caused by the environmental impacts are taken into account. Although it is difficult to monetize external costs objectively, such as pollution impacts, losses of ecosystems and impact on property (Pearce, Atkinson et al., 2006), it is possible to take environmental in account when weighting the costs and benefits.

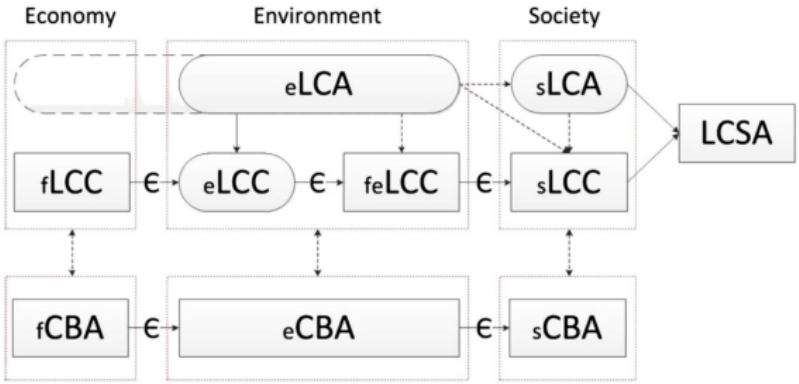

Figure 1: The integrated framework (Hoogmartens, Van Passel et al., 2014)

Life cycle costing (LCC) is a method in environmental decision making (Utne, 2009). LCA, LCC and CBA have sub-methodologies that focus on different aspects of sustainability. LCC is divided in a financial LCC, an environmental LCC, full environmental LCC and societal LCC (Finkbeiner, Schau et al., 2010). When the environmental LCC has

the same scope and same system boundaries as LCA, the LCC can be considered as the 'logical counterpart of LCA for the economic assessment'. LCC should be considered next to LCA, since sustainable products have to be reasonably priced (Kloepffer, 2008). LCC gains popularity as companies aimed to express the added value for money of the asset. Woodward (1997) states the main goal as:

> "LCC seeks to optimize the cost of acquiring, owning and operating physical assets over their useful lives by attempting to identify and quantify all the significant costs involved in that life, using the present value technique"

Life cycle costing was first used in the U.S. Department of Defense in the 1960s. Later on, other industries started using LCC as a decision making tool (Ahmed, 1995). The LCC process identifies all costs over the whole life of a project, including the costs concerning the performance of the object. This tool has different objectives such as evaluating investment options, insights in total costs rather than initial costs, effectively managing projects and making the trade-off between investment decisions that the gives life cycle costs or the total costs for different alternatives (Flanagan, 1983). Wübbenhorst (1986) identifies initiation, planning (conception, design and construction), realization (manufacture, installation and test/introduction), operation (use and maintenance) and disposal/salvage as the phases of the LCC of a project. LCC is a useful tool, as it identifies aspects that should be considered in a life cycle perspective and it increases transparency of future costs. LCC provides insight in the use of public funds and expresses the outcomes in the widely accepted metric 'money'. This makes LCC an understandable method for decision makers and for the public.

5. The (dis)advantages of using life cycle costing (LCC) as a method

LCC is little used today because it has some significant disadvantages. There are some difficulties when using LCC. LCC is considered as highly dependent on information and underlying assumptions of data. LCC requires a lot of data in order to execute the analysis (Cole & Sterner, 2000; Gluch & Baumann, 2004). This makes it difficult and time consuming to execute a LCC study. Second, it contains estimations that are based on future developments and involve many uncertainties, for example the discount rate (Sterner, 2000). This makes it difficult to interpret and use the results and outcomes, as there is no clear yes or no outcome. Additionally, LCC cannot deal with irreversible decisions that might be caused by technological advantages. The availability of data is a third problem. Arja, Sauce et al. (2009) describe the potential usefulness of LCC in the decision making process. They state that decision makers have little knowledge how to implement and handle uncertainties in the operational and maintenance phase. Last, evaluating the environmental impacts on the construction phase is useful. However, the environmental impact on later phases, such as operations and maintenance phase, turns out to cause problems because of the uncertainties (Sterner, 2002). These complications make LCC a difficult and unreliable tool in practice.

6. Applying life cycle costing (LCC)

There are several examples of business cases where LCC is applied as in real projects. It expresses the quality and cost effectiveness in money. The aim of the literature review is to analyze best practices of life cycle management approaches in projects, therefore the LCC of products and assets are not part of the scope.

Nilsson and Bertling (2007) use life cycle cost analysis to analyze the efficiency of maintenance on wind power farms. Condition monitoring system (CMS) is an alternative that monitors the performance of the parts of the wind turbine continuously. By monitoring failures continuously, downtime might be reduced. This might optimize the planning of maintenance management. The total costs for the LCC of the wind power plant were calculated for two cases, Olsvenne2 in Sweden and Kentish Flats in the UK. The LCC is calculated by the cost of investment, cost for corrective maintenance, cost for preventive maintenance, the cost for production loss and the remainder value. The present value of both cases is compared for the initial situation with the CMS alternative, under different maintenance planning strategies. CMS is more likely to be profitable for offshore wind farms, as maintenance is more costly. The LCC study is quantitatively comprehensive. This is possible as there is much data available for both projects, provided by the two companies. The conclusion of Nilsson and Bertling (2007) is primarily expressed in cost efficiency, and the financial impact that one maintenance approach has over the other maintenance approach. Other sustainable aspects, such as the environmental impact do not play a role in this study.

The Swedish rail administration, Banverket, aims to lower its maintenance and operation costs. Nissen (2009) aims to come up with a maintenance decision tool, which is based on LCC. The research compares the costs of three different alternatives of switches and crossings and their cost drivers. This research is based on the maintenance databases of the Swedish rail administration. The total costs are split in a cost breakdown structure. The main costs drivers are inspection cost and periodical maintenance costs. LCC is also of added value to compare the three switches and crossing alternatives. This research applies LCC in a quantitative way and gives clear insights in the driving factors and tradeoffs between alternatives when it comes to maintenance. This LCC study is an extensive and quantitative study. It is clear what alternative is more cost efficient. However, it is difficult to use this information for the decision maker, as the driving forces behind the uncertainties are not well expressed in the LCC case study.

Bull (2015) gives seven examples of executed LCC studies. In chapter 7, Bjorgum, Welte and Hoffmann analyzed corrosion protective coatings for offshore wind turbines using life cycle costs. Different coating systems on offshore wind turbines are compared to find the most effective and efficient coating alternative. The turbine is divided in the submerged, splash and atmospheric zone, which have different levels of corrosivety. Costs of the alternatives are discretely distributed, as uncertainty of input parameters are taken into account. The LCC analysis concludes that the maintenance free coating, that can be used in low temperatures, perform best from a LCC perspective. Nevertheless, differences between alternatives are not significant when considering these uncertainties. Present input parameters are considered as uncertain in the future. If these estimations of uncertainties are improved, it will be easier to use significant results for recommendations.

The three examples of LCC studies shown above are dependent on the amount and the completeness of the data. The first example of Nilsson and Bertling (2007) use scenarios to test the outcomes and come up with a valid conclusion. Driving factors and uncertainties are not explicitly addressed in the LCC study of Nissen (2009). The last example (Bull, 2015) addresses that it is difficult to come up with significant results, as future input is highly uncertain. It is necessary to give decision makers a solid basis for their decisions and take uncertainties and risks into account. The outcomes and difficulties from LCC examples follow the previous outcomes from section 4.

7. Using the outcomes of life cycle costing (LCC) in decisions

LCC studies are regularly applied in defense projects in the Netherlands and Norway. Tysseland (2008) concludes that, although a LCC study is obligatory when purchasing new material, decision makers often make their decision on the initial costs. He states that decisions are often made on initial costs because of the many uncertainties, the information asymmetry between the client and executer, the little knowledge of LCC and a negative attitude towards LCC of the government and project leader. Bakker and Beeres (2015) acknowledge those problems and use the Dutch defense projects as an example. They see that LCC is one of many aspects, next to the power and position of decision makers. Higher investment costs (and therefore lower operational and maintenance costs) are not supported by political reasons, as their term is only four years. Bakker and Beers conclude that none of the decisions are primarily based on the total lifetime costs. They consider LCC as an important estimation tool for the budget and as important input to give insights in the planning but also acknowledge that life cycle costs will not make the difference in the final decision.

8. Conclusion and future research

This literature review examines integral contracting in the life cycle approach and the usability of life cycle costing based on existing literature. Many recent and relevant articles are used to come up with the advantages and disadvantages of the life cycle approach.

Integral contracts gained much popularity in the last few decades. Less handover moments, thus mitigating risks, are major advantages. Nevertheless, handing over all tasks to one contracting party might be risky. Different interests might impact the quality and cost-effectiveness of the project. It is difficult for the decision maker do steer the process, as it is less transparent. An integral contract, such as DBMF(O), might be less profitable than expected beforehand. LCC might be a suitable and very clear method to analyze the (dis)advantages of integral contracting in specific situations and express the alternative in money. This makes it an understandable method in practice, since impacts of different alternatives are expressed in a monetary metric. However, LCC is little used in practice. A large amount of data is needed in order to execute a LCC study. LCC contains little room for uncertainties, which makes LCC a less suitable method to use in practice, since projects are executed on the longer term and should be resistant to changes in the real world. In addition to that, decision makers have little knowledge of LCC and LCC is inflexible as estimations are based on future events.

This literature review gives best practices and complications in executing life cycle costing. A limitation of this study is that, due to constraints, only three examples of LCC studies are highlighted. It would be desirable to analyse additional best practices to have a better overview of the usefulness and successes of LCC in practice. Additionally, it would have been of added value if more examples and direct input of decision makers and practitioners of LCC would have been added within the (dis)advantages of using LCC and applying LCC in practice. Because of the time and scope in which the literature review was executed, relevant literature and information might not be part of this article. Nevertheless, it is believed that a solid basis is set for the literature review with the use of many, high valued articles.

Further research is necessary to increase the ability to use LCC in practice and improve the impact that LCC could have in the decision of the preferable alternative. There are several studies that mention the problems and explain the factors why LCC is

not often used and accepted in the decision making process. Very few of them give examples on how to deal with those problems and how to make the method more suitable in practice. It would be of added value to carry out further research towards a practice oriented LCC method that consider the ideas and solutions of practitioners and decision makers. It is necessary to incorporate flexibility, implement uncertainties and add risk assessment in LCC. These aspects should be added in follow up steps, as LCC is a promising method in the aspiration of increasing the sustainability of our society.

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