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Economic Sustainability by Using Life Cycle Cost Information in the Buying Center: Insights from the Public Sector

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Abstract: Following the triple-bottom-line approach, sustainability comprises not only an ecologic and a social dimension but also an economic one. In that sense, economic sustainability (ES) tries to achieve a state in which present economic activities do not place a disproportionate burden on future economic activities. The time-related dimension of ES is of interest for this research, because procurement management makes use of life cycle cost (LCC), which is an instrument to measure long-term economic effects. LCC information could help to consider ES, but practice struggles to consider the information. This research addresses this issue and merges organizational information processing with organizational buying behavior theory. Empirically, it reports original insights into eight cases in the public sector. Decisions in the cases are usually made by councils (buying centers); as such, a group of people with different backgrounds must be informed with ES LCC information. The findings show ES LCC information requirements, capabilities, and fit, as well as information distribution and perception in buying centers. As such, the cases provide indications as to which decisions in the project are influenced by ES LCC information. Overall, the analysis integrates two theoretical perspectives and provides strong indications that LCC is a promising instrument to link decision making with a sustainability rational.

Keywords: economic sustainability; life cycle cost management; public procurement; case studies; organizational information processing theory

Citation: Gaus, J.; Wehking, S.; Glas, A.H.; Eßig, M. Economic Sustainability by Using Life Cycle Cost Information in the Buying Center: Insights from the Public Sector. *Sustainability* **2022**, *14*, 1871. https://doi.org/10.3390/su14031871

Academic Editors: Paulo Afonso, Antonio Zanin, Orlando Durán and Antonio Boggia

Received: 23 December 2021
Accepted: 2 February 2022
Published: 7 February 2022

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1. Introduction

Scholars identified several causes for companies to commit to sustainability, on the one hand increasing public pressure and on the other the perception that sustainability is a means of long-term competitive advantage [1]. Therefore, most organizations have integrated sustainability in their strategy; however, there are deficiencies to measure sustainability performance in a comprehensive and aggregate way [2]. The question of how to manage sustainability has been discussed for years, and scholars have argued about how economic sustainability can be assessed (e.g., reference [3]).

In this discourse, it is acknowledged that sustainability is not only related to environmental protection. For the sustainability construct, several aspects are of equal relevance: social, ecologic, and economic dimensions of sustainability. Focusing on economic sustainability (ES), the decisions of today shall allow the achievement of economic goals, but they also will allow the achievement of economic goals in the future. In the debate about ES, researchers identify a life cycle cost (LCC) perspective as being useful to assess and measure sustainability (e.g., reference [4]).

LCC typically aims to assess all costs related to a product or project over its whole life cycle. In that sense LCC acknowledges that often the operating costs exceed initial

purchase prices by several times. As such, it would be a sustainable choice to buy a product with a higher price today if lower operating costs can be achieved in the future. Life cycles are widely considered in the discourse about sustainability in general, or for specific applications, such as toys or even circular economies [5–7]. Generally, it is no surprise that cost information and cost structures are seen as appropriate indicators for ES (e.g., reference [8]).

However, even in times of digitalization, the availability of appropriate information about sustainability is still an issue [9]; however, Adams et al. (2014) [10] found that modern information systems provide an opportunity to incorporate measures aligned with sustainability outcomes. Therefore, this work does not question if LCC is appropriate to measure sustainability, but rather, how the measured LCC information is processed and used in decision making.

The majority of papers linked to the topic do not consider how the information is processed [11–13]. They calculate or assess sustainability with LCC and then assume this will directly lead to sustainable behavior [14–17]. However, decision makers need reliable information and they want to be convinced. Then they decide on their evaluation and perception of the presented data. Therefore, the overarching research aim is to understand how LCC information support management decisions that impact ES. It is assumed that LCC is able to assess ES and provide appropriate information to decision makers.

As such, this research refers to organizational information processing theory (OIPT) to examine how LCC might be an important information processing capability that can improve economic sustainability. This object of analysis is embedded in the context of organizational buying behavior theory (OBB), which manifests in buying center (BC) procurement decisions. To the best of our knowledge, this work is one of very few that merges both theories. If information is processed correctly in a BC, this would lead to a procurement decision with positive effects on ES (see Figure 1). The focus in the information processing lies on information measurement, distribution, and use for decision making; effects are only briefly considered. Overall, this research wants to acquire deeper insights into how LCC information is gathered, processed, and used for decision making.

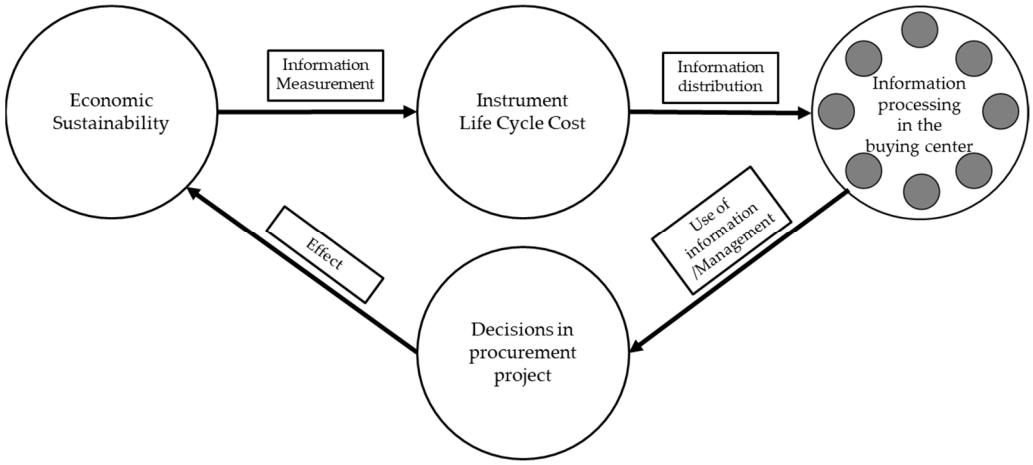

Figure 1. Research focus on the management of ES LCC information in procurement decisions.

For this purpose, this research uses an inductive approach. Empirical cases are investigated in a qualitative way to obtain insights into how and why ES LCC information is processed. The qualitative case study approach follows the methodological guidelines of Yin (2017) [18] and investigates eight cases. The cases provide original insights, namely that the implementation of the sustainability approach is not limited to single institutions [19]. Rather, it has a strong influence on whole supply chains with all involved institutions, e.g., suppliers [20]. Therefore, the focus of the cases is on the BC and its members procurement decisions, because these decisions will have an impact on upstream supply

markets. In particular, this research focuses on public institutions, because they act in several important roles related to sustainability. Glas et al. (2018) [21] refers to the "policy maker and legislator", "leader and pioneer", as well as the "sensitive consumer". As such, public organizations, and their assessment of ES by LCC methods and information processing, seem to be a relevant unit of analysis.

Following the research aim and the unit of analysis, the following questions are addressed:

RQ1: Which LCC information is gathered and reported?

RQ2: Which Buying Center member needs which LCC information, and at what time?

RQ3: Which decisions made by the buying center are influenced by LCC information?

The remainder of the paper is structured as follows: The next section presents the background of ES LCC and its relevance for procurement decisions. It also provides insights into OIPT and OBB. In Section 3, the case methodology is presented. This is followed by the analysis and findings in Section 4. The findings are discussed in Section 5. Finally, this article concludes by noting limitations and providing an outlook for future research.

2. Background

2.1. LCC as an Instrument to Measure ES

The LCC approach, as an instrument for complete and comprehensive cost recording, particularly emphasizes the consideration of the entire life cycle of a procurement object. "Life cycle" is often paraphrased with the colloquial but very catchy term: "from cradle to grave" [22,23]. Although the LCC approach is used extensively in private procurement, the public sector is seen as a key driver for its application [24]. In the course of application, the approach is currently used intensively for the procurement and operation of armaments and transport infrastructure, as well as for the planning and construction of infrastructure in the healthcare and education sectors [12,25–29]. Furthermore, the approach is particularly important in the case of supplier relationships in the form of public–private partnerships (PPP), since a life cycle perspective is generally adopted here [30–32]. In addition, the LCC approach has established itself within the framework of Green Public Procurement [33].

LCC can be viewed from the perspective of the supplier or the client (the contracting authority) [13]. From the client's point of view, the only costs considered are those that are incurred by him. In the procurement phase, these are initially the procurement costs, which generally correspond to the sales price. This includes all costs that the supplier previously incurred in the context of research and development, as well as production. In the usage phase, the operating, maintenance, and repair costs are particularly relevant for the client. In the recovery phase, there are also dismantling and disposal costs [34–36].

A complete record of all costs incurred in the life cycle of a product is associated with a number of advantages. Accordingly, LCC analyses are carried out by various actors for a variety of purposes. From the point of view of public procurement, the objective of economic efficiency is anchored in the federal budgetary law [37]. This rather abstract objective is concretized with an economic feasibility study, with which the economic consequences of a public measure (e.g., a procurement measure) are determined. Ultimately, the results of such feasibility studies are used to support decision making in politics and administration [38–40].

Another purpose of LCC analyses can be an economic comparison of different products or solutions. At the beginning of the public procurement process there is always an identified need. However, there are often different approaches to meeting the requirement, which can differ greatly in terms of their characteristics. In this case, an LCC analysis can be used to show the long-term economic advantages of an alternative solution

[41,42]. As soon as the decision in favor of a solution has been made, the offers of competing suppliers can be compared with one another using an LCC analysis. In contrast to the comparison of the pure purchase price, the long-term economic advantages of a product can be determined in this way [43]. Another objective can be to use LCC analyses for public budgeting. Especially for complex capital goods with high follow-up costs, an LCC analysis can facilitate the estimation of tied budget funds in future periods and can be used as a planning instrument [44].

In order to use the LCC approach from the buyer's perspective for procurement decisions, a procedural approach is recommended. Numerous (process) models for LCC in finance and accounting research have been developed for this purpose in the last few decades, but their basic features are very similar [45]. At its core, five process steps can be identified that must be carried out one after the other. A simplified LCC calculation and analysis procedure is structured as follows:

1. The first step consists of the context analysis of the influencing factors. In addition, alternative solutions are identified and the system boundaries, as well as the usage parameters, are determined [46];
2. The second step is to determine the goal and purpose of the LCC analysis. The resource and time planning for the analysis is also carried out. In addition, the input premises, restrictions, and relevant financial parameters are determined [47];
3. The third step is to agree on rules and procedures. In the course of this, the cost breakdown structure (CBS) is determined and uncertain areas are identified [45,48];
4. In the fourth step, the cost estimation methods are determined and the data collection is carried out. Another component of this step is the implementation of the LCC calculation in the narrower sense, which can be supplemented by a sensitivity analysis. Finally, the analysis is assessed [49];
5. The fifth and last step consists of deriving recommended actions for cost management, as well as documenting the LCC analysis [50].

As already outlined above, in order to record the entire LCC for a procurement object, CBSs are used. For this purpose, all relevant cost elements are first determined and estimated in a further step [49,51]. The purpose of a CBS is to link goals and activities with resources, and to create a logical breakdown of all costs [52]. An essential part of the cost analysis is the identification of cost drivers [47].

The important calculation bases in the LCC approach include dynamic investment calculation methods. The net present value method and the annuity method are of particular relevance [42,53–55]. In principle, dynamic methods are used to include the timing of incomes and expenses and thus, for example, to calculate the advantages of investment objects [56,57]. As part of the LCC approach, all financial flows are to be recorded, whereby expenses are generally considered for procurement purposes [38].

2.2. Reference to OIPT

OIPT gained relevance in procurement and supply management contexts, because new instruments (in particular digitalization) allow and necessitate improved information processing in organizations (e.g., references [58,59]). Generally, OIPT characterizes organizations as open social systems; these aim to execute business strategies through mitigating or managing uncertainty in decision-making processes [59–61]. The core of OIPT is the existence of the need and the ability to process information as a means to reduce uncertainty [62]. Therefore, OIPT consists of three theoretical elements: information processing requirement, information processing capability, and the fit between information processing requirements and capabilities [61]. In this research, we examine all three, considering ES LCC information in organizational BCs.

First, information processing requirements define the amount of information required to allow decision making, considering a particular set of decision objectives [61]. Briefly, OIPT requirements are the artefacts for describing information quality, quantity, timeliness, and the general validity and reliability issues that are related to a specific

uncertainty in decision making. Uncertainty is an important topic in sustainability contexts, and it ultimately affects the degree to which organizations deliver sustainability performance [63]. Uncertainty results in ambiguity regarding the organizations and their interpretations and perceptions of the best sustainable decision alternatives. Uncertainty about sustainability is interpreted as an information processing requirement for decision makers.

This requirement stimulates organizations to build up processing capabilities. Information processing capability is an organization's ability to gather, interpret, and synthesize information that supports decision making [61]. Today, organizations use advanced information processing capabilities, e.g., digitalized business analytics. One instrument, LCC, is the focus of this paper. Referring to previous research (e.g., reference [4]), LCC can become an instrument to improve information processing capabilities for sustainability purposes.

Finally, OIPT aims for a "fit" between requirements and capabilities. Here, sustainability performance is increased if information requirements and information capabilities fit well. This also explains and justifies the effort to increase information processing capabilities in organizations. However, it is important to consider the fit. The absolute amount of information processing capability is not relevant. Too much capability is inefficient, less capabilities are potentially ineffective.

Finally, we perceive OIPT to be well suited for our research, because OIPT considers changes in information requirements, e.g., due to time dynamics [60]. Today, organizations experience changed requirements related to sustainability information. In particular, this research refers to ES information. LCC is then a means to increase information processing capability.

2.3. The Link to Procurement Decisions in the BC

In order to analyze how ES LCC can be used in procurement decisions, this section provides insights into the structure and organization of procurement decision making. The involved persons and their organizations in the decision-making process have long been relevant subjects of analysis in procurement research [64,65]. Overall, the topic is discussed and linked with the research stream of OBB theory [66]. OBB has its origin in marketing research, but it can explicitly help buyers to break up the procurement decision process systematically [67,68].

OBB models the procurement decision in an organization as a process, in which the demand is specified and alternative suppliers/offers on the market are identified, evaluated, and chosen [69]. OBB is strongly connected to a specific situation [70], but specific situations are considered in the structured and formalized process [68]. Notable situation-specific factors are the different objectives, value conceptions, and expectation attitudes of the involved participants [67]. This is peculiar, because in OBB, the buying decision is usually influenced by different persons and different preferences; varying perceptions and expectations, of course, influence the buying decision [71].

Webster and Wind (1972) [67] have defined the procurement committee as the BC. The BC can be seen as a subunit of the buying organization, in which several people, usually from different departments and with different backgrounds, work together for a limited period of time in order to make a joint procurement decision [72]. Webster and Wind (1972) [67] defined five different roles that are usually active in a BC: the user, the influencer, the decider, the buyer, and the gatekeeper [67,73]. It is not mandatory that five different persons belong to the BC. Rather, it is possible that one person in the BC can take on several of the five roles, or that the participants in the buying process are changing in different stages of the procurement decision process [74]. The multi-role/multi-person composition of a BC and its power, politics, interactions, and information controls have for a long time been researched (e.g., reference [74]). However, it is still the subject of recent research that found that information alone is not sufficient; instead, the correct information processing is required (e.g., reference [75]). Still, how "right" information

processing is established in a BC is not sufficiently answered, especially if we consider the public sector and the high political influence on procurement decisions.

The information processing challenges in a BC is the reason why this research links OBB with OIPT theory. In particular, recent research [75] found that the conventional opinion—sharing all information in a BC is a sure-fire way to gain success—is not true. Instead, a measured, deliberate approach seems to be more effective if expert or legitimate power is added. In other words, the correct information does not help if it is not processed in a suitable way. This is a key initial assumption of this research: the lack of ES recognition in procurement decisions is due to the inappropriate information processing of ES LCC information. Therefore, we examine information processing in the BC by following the three elements of OIPT (requirements, capabilities, and fit).

3. Methodology

3.1. Case Study Method and Multiple Case Design

The case study methodology follows an explorative, qualitative research approach. As such, the case study research is able to obtain deep insights into organizational processes and organizational structures. Therefore, the case study research is well suited to our research aims. Furthermore, the case study methodology is particularly suitable for answering "how" and "why" questions. Since such questions are the focus of this research, the advantage of this case study approach is obvious. In addition, this case study methodology is often applied to analyze life cycles and ES [6,7,76] due to specific context factors, such as a unique situation, a long-term time frame, and high complexity. Similar context factors are also expected in the analysis of ES decision making in BCs.

Another advantage of the design is seen in the possibility to investigate a complex issue under the consideration of several factors and their relations to each other. Having the possibility to jump back and forth, an iterative process of gaining knowledge can be applied. In this research, this is advantageous, because we were able to deepen the investigation depending on gained insights.

Following the case study definition by Yin, we understand a case as an "empirical inquiry that investigates a contemporary phenomenon (the "case") in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident" ([18], p. 16). If several cases are analyzed, it is a multiple case study design. Then, a cross-case analysis enables the researchers to combine findings and results from each single case. Multiple case study designs are considered as being more robust if case selection logic is appropriate. With a number of six to ten case studies in an effective arrangement, it is possible to identify support to related research questions and propositions [18]. Therefore, this research addresses an equal number of eight cases. The selection of cases follows the replication logic of multiple case designs, meaning that each case is linked to the same phenomenon and its context. Here, all eight cases are embedded into the public procurement context with three groups of peculiar contexts to defense, mobility, or infrastructure procurement (Figure 2).

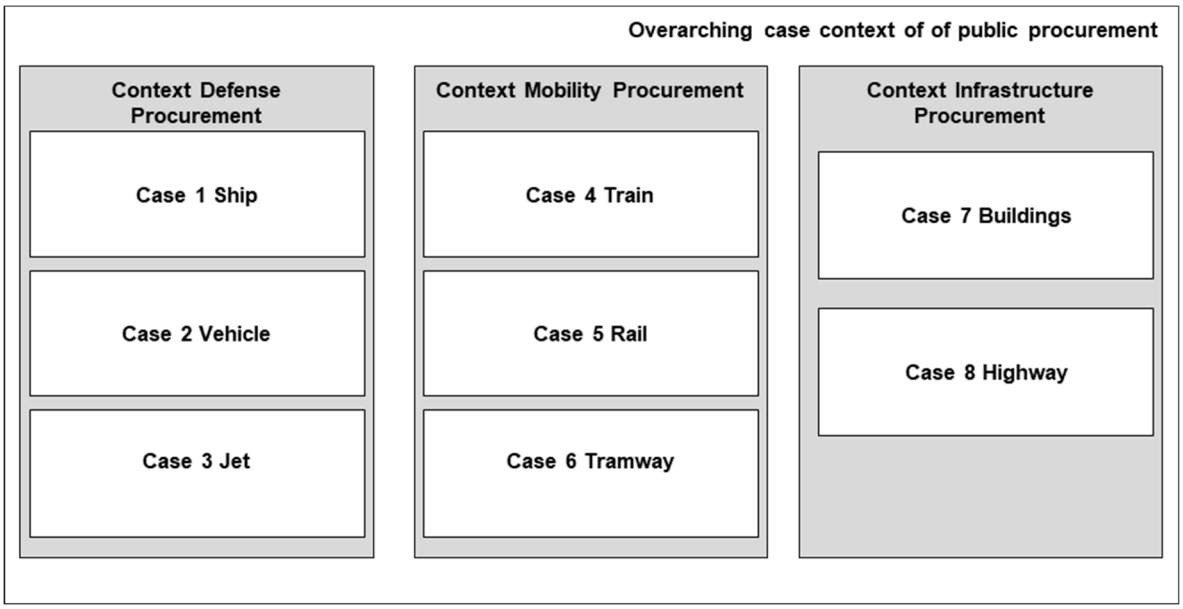

Figure 2. Case study structure.

The case selection considered the replication logic. First, each case was assigned to the public sector. Second, each case addressed the demand for a high-priced product with a long operating life (30 years or even more). Third, in each case a formalized procurement process was executed, in which the participation of several persons is necessary (comparable to a BC). Finally, in each case, ES LCC information is used. All presented eight cases shared the mentioned characteristics.

3.2. Data Gathering

Data collection in the cases was divided into two parts. First, a structured review of sustainability literature in public sector procurement was conducted in order to identify information about the context and to set the basis for a systematic analysis. Based on the findings from the review, key aspects were merged and used as the basis for the second part of data collection: the case investigation with qualitative expert interviews. Interviews were chosen because these allowed deeper insight into phenomena.

In the present study, the expert interview was semi-structured. Key aspects were questioned with open questions, while there was also room to add or deepen specific aspects. The advantage of the partially standardized expert interview was seen in the open conduct of the conversation and the possibility of being able to deepen insights. In this way, topics that had not yet been covered could be integrated into the research process and considered in the further investigation.

The interview respondents had all key functions in the BC of the case. The respondents had the following functions: Chief of Procurement, Chief of Planning, Project Manager, Procurement Manager/Advisor, or Head of Commercial Project Management. Overall, 15 interviews with 23 respondents were conducted, which led to 165 Pages of documented interview material.

Before the data collection, the interview agenda and procedure were evaluated by six academic colleagues. They were asked to examine the interview procedure and questions regarding comprehensibility, completeness, and structure, as well as ambiguity. In this way, the structure of the interview guideline was enhanced. After finalization, the interview guide was sent to the interviewees by e-mail in advance for preparation.

The interviews were conducted personally on site whenever possible and only in exceptional cases by telephone. Each interview was carried out by two researchers due to triangulation reasons. The answers were documented during the interview by hand in a protocol template. After the interview, the handwritten notes were digitally recorded,

transcribed into an interview protocol, and reviewed by both interviewers. Subsequently, the interview protocol was sent to the interviewees for review and validation. With the help of this step, it was ensured that the documented contents were checked for completeness and correct presentation. During this step, if necessary, there was the possibility to clarify open questions from the interview, and to include further remarks and supplementary comments in the documentation. In a final step, the documentation was approved by the interviewees. Only approved interview protocols were included in the research process.

4. Case Description and Analysis Results

In the following section the results of the multiple case study are presented. First, we briefly report on the overarching public procurement context of the cases (Section 4.1). Then, the cases are presented in clusters of defense (Section 4.2), mobility (Section 4.3), and infrastructure (Section 4.4). The case findings are consolidated in a cross-case analysis (Section 4.5).

4.1. Public Procurement Case Context and ES LCC

The need to carry out profitability studies in the public sector due to national legal regulations has already been mentioned. In addition, however, there are other (legal) framework conditions for the use of LCC in the cases that are embedded in the context of the EU public procurement.

First, we point to the Europe 2020 strategy for smart, sustainable, and inclusive growth-taking, in which the European Commission has highlighted LCC for public tenders [77]. In the context of sustainable public procurement, LCC is valued as an important element to expand the paradigm of the single purchase price. With the 2014/24/EU directive, which had to be transposed into national law, external effects, e.g., environmental impacts, can now also be considered in the LCC calculation [78]. Therefore, the case context brings a situation in which sustainability, as well as LCC, is relevant.

Second, it is worth mentioning that the methodology for using LCC is still at the discretion of the contracting authority, although methodology guidelines are prescribed, e.g., for road vehicles [79]. The use of LCC in public procurement is currently still optional, but will become mandatory if a methodology is available from the European Commission [80,81]. This means that we expect the cases to have their own approach to process information about ES LCC.

Besides this, it is worth mentioning that the cases are all embedded in the context of EU public procurement. However, if the findings provide insights as to why and how ES LCC is helpful, then public procurement in other legal contexts may also profit from this research.

4.2. Defense Cases

Defense procurement projects are often accompanied by high procurement costs and long utilization phases of the considered products and systems. The utilization phase of a military system usually takes 30 years or longer. Approximately 70% of the total life cycle costs of military systems are attributable to the utilization phase, which makes it reasonable to consider the total life cycle costs of the systems [82]. However, around 80% of the life cycle costs are already defined in the design and development phase of military systems. Therefore, the optimization of ES should happen as early as possible, i.e., in the procurement decision-making phase. It is remarkable that procurement decisions in defense of course follow a military, but also an industrial policy logic, while optimization of ES is a relevant but not dominant objective for many members of the BC. The BC in the defense cases is mainly established by a committee named the "integrated project team", to which different members and actors from the armed forces contribute (planning, budget, and logistics, etc.).

Case 1 Ship: This case is about the procurement of multi-purpose frigates for the German Navy. The procurement volume for the planned four units amount to around EUR 5.3 billion, and includes the design, construction, and delivery of the ships. An option for the procurement of two further units has been included, as the Navy's procurement requirement has been assessed at six units. The interviewee was the head of the buying center.

In view of the defined arms budgets for the armed forces in general, and the navy in particular, the expectation was that no significant increases can be expected in the coming years. This means that the available budgets must be used optimally and invested sensibly in the long term. Therefore, ES was a leading goal for the BC. However, the interview revealed that the problem was to obtain suitable ES LCC information and to communicate it to specific members of the BC: *"With regard to ES LCC, three factors are particularly important: 1. cost transparency, 2. forecasting, 3. answering questions, especially from the political and parliamentary sphere."*

Referring to information needs, the BC was aware that ES LCC information is important as a basis for reporting in the political parliamentary arena, since it was necessary to obtain approval for the procurement of new ships from the highest political level. From an information capabilities point of view, the BC used LCC as the central tool for supporting the procurement decision. In-house specialists for cost analysis and external consultants were tasked to execute and evaluate LCC computations. However, there was also the need to be open for additional information processing capabilities from the supplier side. So, the BC defined LCC as an award criterion. The bidders were obliged to carry out an LCC forecast for their ship designs and attached this information as a basis for their bid calculations. The amount of the total LCC has been evaluated by the BC using an evaluation matrix. In other words, parts of the information processing happened at the supplier side. Finally, the information fit was assessed. Here, the different BC members had to be provided with differently detailed ES LCC information at different times during the decision-making process. While the project management level had to have very detailed LCC information about each subsystem installed on the ship, the political level was supplied with LCC information at the overall system level. The interview assessed this as a robust and feasible way to inform the BC members. Besides this, it was appreciated by the interviewee that the detailed LCC documentation supported cost transparency and the identification of critical cost drivers. *"The initial cost estimate of the project was rated as very good. Furthermore, it enabled a detailed cost determination and created the necessary cost transparency."*

The following aspects summarize ES LCC information processing in the BC of the case:

- ES LCC as a relevant information requirement in order to keep open the possibility to procure not only four but even six units of the ship in the face of restricted budgets;
- Development of a ship and cost model as central information processing capabilities with the help of internal and external parties and the contribution of supplier information processing capabilities with their LCC calculations following award criteria;
- Consideration of ES LCC was reviewed by the German Government Accounting Office, and ES LCC has been regularly reported across different management levels. Stepwise increase in details about ES LCC information depending on stakeholders is assessed as a positive strategy for information processing.

Case 2 Vehicle: This case is about the procurement of infantry fighting vehicles for the German army. About 350 vehicles are already delivered to the army. Up to 220 more vehicles should be procured. The procurement volume for the new units amounts to around EUR 5.3 billion. The interviewee was the head of the project and head of the buying center. Because of the high complexity of the acquisition project, hundreds of stakeholders were involved in the project. These stakeholders have been drawn together for the project from numerous specialist departments within the procurement organization. Each stakeholder has been involved in the BC because of their specific expertise. For

example, various technical or legal departments have been involved. However, the interview was focused on core stakeholders of the BC with relation to ES LCC information.

Due to the further development of technical solutions in vehicle development, there was a need to upgrade the vehicles already delivered. As the planned upgrade was very expensive, several ES LCC information requests from BC members exist in that area. There was the need to clarify if the upgrades of the vehicles made sense or if the procurement of additional vehicles was more advantageousness. In addition to that, an ES LCC information request about the utilization costs for the vehicles exists. In the long term, the utilization costs of the fleet are decisive for the total budget required for the project. Therefore, the ES LCC estimation for the existing fleet was important for the BC. LCC information was not available for the project at that time, although the system was already in use. As this kind of information was not available at the very beginning of the procurement project, the BC requested this information in order to find a proper procurement decision for the upgrade problem.

> *"An LCC analysis would have been clearly advantageous at this point, as the costs of use and the required budget could have been forecast at an early stage using the data from the LCCM."*

In order to obtain the necessary ES LCC information, there was a need for a fast LCC estimation. Since the project had no experience with LCC estimation at that time, but wanted to use it as a decision support tool in the long term, an external company was contracted to develop a database-driven LCC estimation. The development of the database has been performed in close collaboration between the procurement project, the in-house cost competence center (CCC), and the external company. The LCC estimation database was able to collect all costs associated with the project. The LCCs are reported on the level of different cost elements, a simulation helps to estimate the LCC in the future, and cost driver identification is possible.

Concerning the information fit, the BC, with the help of this database, was able to cover different information requests. While the project management level is able to generate very detailed LCC information about each subsystem installed in the vehicle, the political level can be supplied with LCC information at the overall system level. The interviewee assessed this as a robust and feasible way to inform the BC members. Besides this, it was appreciated by the interviewee that the detailed LCC documentation supported cost transparency and the identification of critical cost drivers.

> *"The project intends to use the results of the LCCM […] for the preparation of reports and for more precise forecasts."*

The following aspects summarize ES LCC information processing in the BC of the case:

- The information request for a short-term ES LCC estimation could not be met by own capabilities;
- The BC's procurement decision should be based on reliable ES LCC forecasts;
- The development of an LCC database seemed to be a good solution for informing BC members.

Case 3 Jet: This case describes the procurement for multi-role fighter jets. The current plan is to procure 38 additional aircraft. The procurement volume was around EUR 5.5 billion. The interview was conducted with the head of the project, the head of commercial project management, and the project manager who was responsible for the LCC estimation. The head of the project was the head of the BC.

Due to a lack of cost transparency within the project, the German Government Accounting Office (GGAO) had been instructed to collect LCC information in order to acquire an overview of the current financial situation. Without the necessary cost transparency, it would not be an option for the GGAO to support investments of the fleet in the future (e.g., upgrades). The GGAO plays a very special role here, as decision makers at

the political level, in particular, take the GGAO's findings and recommendations into account in their decision-making processes, for example, when approving budgets. Therefore, the primary objective was to identify all cost elements associated with the project for the transparency of future budget planning.

> *"LCC information is needed to refine cost estimates to justify necessary budgets (on a parliamentary level)."*

Referring to this, the task of the BC was to obtain a clear overview of the current spending situation. In order to be able to procure the necessary support from the GGAO, and therefore from the highest political level, it was absolutely important to collect the cost information in a structured and consistent way. From an information capabilities point of view, the BC used the LCC logic as the central tool for collecting all cost information from the jet. The collected LCC information was also the basis to estimate the utilization costs of the jet in the future.

First of all, it can be stated that the already-existing project team did not have the resources, skills, and abilities to conduct their own LCC estimation. Therefore, an external service provider was assigned to develop a unified concept for capturing the jet's LCC. For the collection of the LCC information, the existing specifications for the collection of LCC in the MoD have been used. This was intended to enable a uniform collecting and reporting of the results. The focus of the LCC capture was clearly on creating cost transparency in the project. The amount of the individual cost elements was initially of secondary importance.

A particular challenge was the cross-project collecting and systematization of the LCC, since numerous other projects provided input for the jet project. This included, for example, the procurement of radio or radar equipment, as each is coordinated and implemented in a separate project, but after realization they merged into the overarching jet project. The creation of cross-project cost transparency was also intended to enable the identification of cost drivers in order to create the possibility of strategic and thus economically beneficial fleet management.

Similar to the project described above, the contracted company developed an LCC database, which enabled a cross-project LCC estimation. The LCC estimation database helped to collect all costs associated with the main project on the cost element level described in the MoD manual. A forecast of future costs is not possible yet, but is currently being developed in order to obtain relevant information about the necessary budget for the fleet operation.

Concerning the information fit, the BC was able to cover the information requests from the GGAO and the political level. The project leader was able to obtain information about cost drivers on the system or subsystem level. This, in turn, helped to compare cost drivers with other nations and to see if they have identified similar cost drivers. This enables the use of the LCC in the sense of ES LCC information.

> *"The main objective is to ensure the required availability of the weapon system (to provide as many jets as possible ready for deployment) at the most economical conditions—in the long-run."*

The following aspects summarize ES LCC information processing in the BC of the case:

- Creation of cost transparency was the main driver of the LCC estimation;
- Development of resources and skills for LCC information processing during the project;
- Support from an external company as an additional information processing capability;
- The development of an LCC database seemed to be a good solution for informing BC members.

4.3. Mobility Cases

The provision of local and long-distance public transport services is one task of the public sector. In order to be able to provide these mobility services, there is a great need for appropriate vehicles. The demand includes, for example, trains for long-distance traffic, as well as streetcars for urban traffic. Regardless of long-distance or regional transport, these vehicles have common features. All trains usually have long service cycles. A period of 30 years or more is not uncommon for trains and streetcars. High procurement costs also go hand in hand with the acquisition of new trains and railroads. Due to the long utilization cycles, there are also high costs for the operation of trains and streetcars that have to be borne by the operator of the mobility services. However, there is a need for high availability in order to operate the fleet in an economic way. The fleet sizes must also be optimally planned so that no unnecessary trains are procured and operated. This results in a complex optimization problem between actual demand for transport line capacity, reliability, and availability of the fleet, and the associated procurement and utilization costs. The presented case studies of the mobility cluster address the above-mentioned challenges by processing LCC information.

Case 4 Train: The case is about the procurement of trains for long-distance passenger transport in Germany. There are plans to buy up to 300 trains, with a procurement volume around EUR 5.5 billion, which includes the design, construction, and the delivery of the trains. From the very beginning, a purchase commitment of 130 trains had been agreed, which can be extended to up to 300 trains if required. The interview was held with the head of the project, the head of commercial management, and the head of technical solutions. The head of the project also had the role of the head of the BC.

The procurement of the new train fleet was aimed at the gradual replacement and standardization of the existing train fleet. As a result, three different train types have been replaced by the new train as part of the procurement project. While train type 1 has been in service for almost 40 years, train type 2 has been in service for about 20 years, and train type 3 has been in service for 15 years. Due to the high average age of the train fleet, it was assumed in the run-up to the procurement planning that the maintenance expenses for the currently operating trains alone would increase by 8.2% per year. In this respect, it has been anticipated that the costs of operating the train fleet will rise more sharply in the future, making it more difficult to operate the fleet economically.

Regarding the information needs of the BC, it was clear that the procurement of a new generation of trains would affect the business for the next 30 years. In order to obtain the approval for buying new trains, many different LCC information requests had to be met. In addition to the realization of the technical requirements for the new trains, the information requirements focused primarily on the costs in the utilization phase. These costs shall be considered for making the procurement decision. An ES LCC estimation was therefore planned for the project.

> "*It is important that LCC is recorded as accurately as possible in the early project phase, as this is where the influence of LCC appears to be greatest. This plays an important role in resource planning*."

From an information capabilities point of view, the BC used LCC as the central tool for supporting the procurement decision. The core requirements for the new trains had been firmly defined in advance by the project. With the help of this specification, the possibility of a price-based evaluation of the performance requirements has been achieved. A particular challenge was the development of a suitable CBS, as this had not yet been defined at the start of the work. With the help of an ES LCC estimation, the main cost drivers in the utilization phase of the train fleet could be identified and also used as an evaluation criterion for the award procedure. The BC defined LCC as an award criterion. Electricity consumption, personnel expenses, maintenance expenses, and cleaning expenses have been identified as the main cost drivers. In order to be able to estimate the LCC of the different train designs, a utilization profile of the trains was developed and given to the

bidders. Based on this utilization profile, the evaluation of the proposals (with a strong focus on the cost drivers) was conducted. In this way, the cost drivers could already be considered in the train design and the overall concept could be developed as cost-optimally as possible. In order to be able to secure the LCC forecast from the bidders, it was planned from the beginning to contract the main cost drivers with the bidders. This created an incentive for bidders to provide the most detailed and accurate LCC estimation possible. The information fit was assessed by the BC by comparing the different train designs and offers. An external consulting firm was retained to review the bids and evaluate compliance with the technical requirements in conjunction with the designated LCC. The ES LCC information was then used to select the most economically sustainable offer. This information, in turn, has been used as the basis for obtaining commitments throughout the organization. The following aspects summarize ES LCC information processing in the BC of the case:

- Establishment of fixed performance requirements for the fleet as a target for suppliers;
- Identification of the main cost drivers;
- Definition of LCC as an award criterion;
- Development of a train-utilization profile as a common basis for bid evaluation (legal certainty);
- Support from external third parties for validation of the LCC from the suppliers.

Case 5 Rail: This case is about the procurement of new trains for local passenger transport in Germany. The plans were to buy 82 trains, with a procurement volume around EUR 1.7 billion, including the construction, delivery, and maintenance services for the trains. The interview was held with the head of the project and the head of commercial management. The head of the project also had the role of the head of the BC. The peculiarity in this project is the composition of the BC. Since the procurement of the new trains is embedded in an overall project with the simultaneous procurement of new rail infrastructure, a political representative of the government is represented in the BC. At the same time, the trains are being procured on behalf of municipal transport associations, which are also members of the BC.

The fact that the procurement of the new trains was not carried out by the municipal transport associations themselves had economic reasons. By bundling the procurement requirements, the federal state hoped to obtain improved purchasing conditions and significantly better conditions during the trains' utilization phase. Therefore, detailed ES LCC information was very important for the BC and the procurement decision. In order to obtain an economically advantageous procurement decision, the BC was obliged to collect the appropriate ES LCC information at a suitable time, and to report the information with the necessary details to the several members of the BC.

> *"For the procurement decision, three aspects were of particular importance to the BC: acquisition price, monthly availability fee, and energy consumption for 30 years."*

From an information capabilities point of view, the BC used LCC as the central tool for supporting the procurement decision. Numerous technical, as well as monetary requirements, have been defined for the procurement of the train fleet in order to be able to meet the needs of the public buying authority. The consideration of LCC estimations as an evaluation tool has not been considered from the beginning of the project. Rather, the focus has been placed on aspects such as compatibility, reliability, sustainability, or comfort for the passengers. In the course of the project, the LCC estimations became more and more important, because an economic evaluation of the previously defined criteria with the instruments used so far was not possible in a sufficient way. The information requests from the BC could not be answered. In particular, it was not possible to adequately assess sustainability targets. Therefore, the implementation of LCC has been enforced.

In addition to the LCC, availability was defined as one of the main focal points for the procurement project. To this end, an availability contract was concluded with the

manufacturer in which the 100% availability of the train fleet was stipulated in order to be able to adhere to the planned train schedule. Availability is thus a key performance indicator that influences the required overall size of the train fleet. The fleet size, in turn, has a direct influence on the overall LCC. On the one hand, due to the procurement costs and on the other hand due to the operating costs.

The technical information was then merged with the associated price/cost information by evaluating the bids. In addition to the prices for the new trains, the bidders also provided information in their bids on the planned costs for the operating phase. Therefore, the information fit could be achieved. The following aspects summarize the ES LCC information processing in the BC of the case:

- Establishment of fixed performance requirements for the fleet as a target for suppliers;
- Identification of the main cost drivers;
- Definition of LCC as an award criterion;
- Development of a train-operation profile as a basis for bid evaluation (legal certainty).

Case 6 Tramway: This case is about the procurement of new trains for local passenger transport. The plans were to buy 119 trains, with a procurement volume around EUR 562 million. The procurement volume also includes necessary maintenance services. The contract period for the maintenance services covers a total of 24 years. There is also the option for procuring a further 37 trains on the same terms, as agreed in the main contract, if the current demand forecast for train capacity is insufficient. The interviewee was the head of the project who was also the head of the BC.

In addition to the technical requirements, high economic demands were placed on the train project. The BC therefore had to take these requirements into account from the outset, as it was not considered possible to provide additional budgets. In addition, the consideration of LCC has been driven by the fact that the maintenance costs of the procured vehicles increased enormously after a moderate phase at the beginning of usage phase. During the first 2 years of use, guarantees with suppliers were firmly anchored within the procurement contracts and maintenance costs were intensively monitored. The effort and costs required for maintenance services were relatively low during this phase. However, these costs increased massively when the warranty commitments expired. The consideration of LCC estimations was therefore a goal for the BC from the beginning.

> "One of the main objectives was to reduce vehicle maintenance costs and increase fleet reliability throughout the life cycle."

From an information capabilities point of view, the BC used LCC as the central tool for estimating the fleet costs in the utilization phase. Besides the technical requirements for the fleet, it was a requirement of the procurement authority that the necessary maintenance measures should take place in the company's own workshops and by its own personnel, but under the supervision of the manufacturer. Therefore, LCC estimation was performed in two steps. While the manufacturers had to calculate LCC for their trains, the LCC estimation for the personnel and infrastructure components were provided by the procurement authority. For this purpose, experience values from past projects were used for the most part.

This means that the profitability analysis was no longer limited to the actual procurement project, but was also extended to overarching areas. The fact that the maintenance services were carried out by the company's own personnel was mainly due to the fact that the employees are employed by the city and cannot be released. Therefore, the different information needs of the BC members could be met. While the city was interested in integrating the existing staff in addition to the economic procurement of the trains, the procurement project was primarily interested in an ES operation of the fleet.

The information fit was assessed by the presentation of the LCC estimations on different levels. The LCC had a strong focus on costs for maintenance personal and

infrastructure at the political level and LCC estimations for procuring new trains and the costs in the operating phase were prioritized at the project level.

The following aspects summarize ES LCC information processing in the BC of the case:

- Procurement of new trains and maintenance contract for 24 years at the same time;
- Consideration of own maintenance infrastructure and personnel in LCC estimation;
- The focus of the LCC estimation is on the control of maintenance and repair measures, as these have been identified as the main cost drivers.

4.4. Infrastructure Cases

In order to be able to guarantee the provision of services to citizens, there is a need for suitable infrastructure. This infrastructure, such as office buildings and city halls, but also schools or kindergartens, must be procured and operated by the public-sector clients. The same applies to road and rail infrastructure. Here, the public buyer is responsible for construction and maintenance as well. When looking at road infrastructure, as well as building infrastructure, it becomes clear that both types of infrastructure have commonalities. The procurement of infrastructure is associated with high procurement costs, the life cycles have a length of 50 years or more, and the costs for operation and maintenance are high. Therefore, public authorities are looking for tools and concepts that support long-term sustainable decision making. It can be stated that methods such as LCC estimations are used more frequently to improve the overall economic viability of different alternative solutions. Furthermore, the public sector is often faced with scarce funding. As demands for new buildings and road infrastructures increase, backlogs are emerging that necessitates better funding management. All this relates to the ES LCC topic.

Case 7 Buildings: The case is about the procurement of new building infrastructure for public organizations. This case does not consider a specific procurement object, but shows how LCC estimations can be considered in the evaluation of infrastructure procurement projects. The interview was held with the head of a task force who advise local and municipal public clients on the procurement of building infrastructure. In this role, the interviewee is regularly member of a BC as head of commercial management.

According to the interviewee, strict budgetary constraints regularly present a starting point for procurement authorities. It is therefore important to keep the costs associated with procurement and operation low and predictable. For an economic evaluation of the procurement decision, LCC is therefore regularly used as an evaluation criterion for the infrastructure sector. The information requirements refer on the one hand to the procurement costs and the questions of when and in what amount the budget is available.

In the majority of cases to which the interviewee responded, an existing property is available but requires extensive modernization. Then, the question is whether the existing building should be completely modernized or replaced by a new building. In addition, information is requested if a combination of several building projects into one project is possible and beneficial (community center). At the same time, solutions for operating the infrastructure should be included the decision-making process. This can either be performed by the public sector client itself or outsourced to an external supplier. Actors are tasked with processing all of the cost information of the different alternatives.

The information requirements are defined by the BC before the tendering process begins. Requirements include, for example, the planned type of use, an assumed utilization profile for the property, or information about the planned lifecycle. All requirements are then published in the call for tenders. The bidders are required to submit their bids including the required LCC estimations. Since the LCC is defined as an award criterion, an evaluation of the costs is based on the LCC.

The information fit is regularly fulfilled with the evaluation of the offers, when all LCC information and the corresponding solution proposals are available. Thus, a cost

evaluation can be performed. Main cost drivers are identified and evaluated by the BC members.

> *"The use of LCC has led to an increase in economic efficiency, as aspects such as energy consumption are now included in the overall evaluation, which accounts for a high proportion of the total costs".*

The following aspects summarize ES LCC information processing in the BC of the case:

- Defined LCC as an award criterion for alternative solutions;
- Development of a utilization profile as a common basis for bid evaluation (legal certainty);
- Utilization cycles between 15 and 30 years.

Case 8 Highway: This case is about the procurement of new, and the sustainment of existing, highways in Germany. This case does not consider a specific procurement case, but shows how LCC estimations are considered in the evaluation of highway infrastructure procurement and sustainment projects. The interview was held with the head of commercial management. In this role, the interviewee is regularly responsible for the commercial evaluation of procurement projects and, in addition to that, is a member of BCs. The structures of the BCs are typically quite heterogeneous, which has a direct impact on the information requirements of the members.

While the members of the political level are primarily interested in the availability of the road infrastructure, the members of the project level are primarily interested in the most economically advantageous realization of the infrastructure projects. Using ES LCC seems to be an appropriate solution to meet both goals.

> *"LCC and LCCM are evaluated as target-oriented concepts for the procurement of complex capital goods (in particular transport infrastructure and goods for building construction)."*

ES LCC is suited to inform the political level, because the development and evaluation of solutions for the achievement of the availability requirements takes place with the help of monetary considerations. Thus, for example, it can be justified that an initially more expensive procurement solution can be economically more meaningful if fewer maintenance measures are necessary in the utilization phase. This can be the case, for example, if high-quality road pavement is used that requires less maintenance. This has a direct impact on maintenance costs and the availability values of the road. The provision of information to the political level is of particular importance, because here the budget approval for the procurement projects takes place.

In order to be able to carry out this type of information processing, a wide range of expertise in conducting host liability investigations has been built up within the organization. With the help of these studies, different implementation solutions can be compared with each other without consulting external support. Usually, no additional ES LCC information capability will be required by the BC. All information requests will be satisfied by internal resources.

LCC is defined as an award criterion, so that bids are evaluated and awarded on the basis of LCC knowledge and the bidders are requested to specify the LCC of their proposed solutions. Considering empirical data from past projects, and based on the results of the economic feasibility study, the bid evaluation is then carried out. During this step in the process, the information fit is assessed. The political level is typically informed on an aggregated level. The information of the project team is very detailed. The interviewee states that it may not be possible to cover all information needs. One cause is that past data is not available because there is no electronic database for storing and evaluating this project and cost data.

> "*However, numerous opportunities for a successful application of LCC are seen, e.g. extensive historical data, innovative contract concepts, suitable competitive structures,*

qualification of decision makers, and the development and maintenance of a usage database, as well as a suitable legal and cultural framework, but capabilities are not always given."

The interview assessed, that using the ES LCC approach significantly helped to inform different stakeholders in the process, as well as the members of the BC, in order to reach the procurement goals. The following aspects summarize ES LCC information processing in the BC of the case:

- Extensive know-how for the execution of economic efficiency studies available in-house;
- ES LCC information as a basis for informing Parliament to achieve budget releases;
- Use of historical ES LCC data for project/tender evaluation;
- Instrument for the selection decision of the most economical solution.

4.5. Cross-Case Analysis

In fact, the observed eight cases are very specific with regard to their procurement object and their wider effects on the public sector and society. From an ES LCC perspective, they are quite close to each other, because they are projects about costly and complex investment goods with long life cycles. Therefore, procurement objects are, at a first glance, heterogenous, but homogenous in their cost, time, and complexity characteristics. Therefore, we are able to execute a comparison analysis along the key constructs of OIPT (see Table 1).

Table 1. Cross-Case Analysis.

Case	Information Processing Requirements		Information Processing Capabilities			Information Processing Fit Assessment	
	LCC Information Requirements	**Purpose of the LCC Estimation**	**Execution of the LCC Estimation**	**Tools or External Support Applied**	**Existing Skills and Capabilities**	**Reliability of LCC Estimation**	**Management Under Consideration of LCC**
1 Ship	• Structured distribution of LCC in a CBS; • LCC information requests on four primary cost elements: procurement, staff/training, logistics and infrastructure; • LCC information requests from the system to the subsystem level.	• LCC to set a cost ceiling in the acquisition project; • Own cost model for validation of the designs; • LCC as tender criterion; • LCC as long-term calculation and controlling instrument; • Using of LCC information for reporting to different stakeholders (e.g., Parliament, MoD, GAO).	• Own estimation of expected LCC for the entire system; • Request for estimation of expected LCC for the overall system, as well as the subsystems, by the bidders.	• External support for ship cost-model; • External support for preparing the LCC tender documents; • OPUS Suite for LCC calculation.	• No existing LCC skills in the project team; • Support for collection, analysis, and evaluation of self-generated LCC estimation by the cost competence center (CCC) in the procurement agency.	• Regular review of LCC estimation with experience of other (ship) projects.	• Creation of cost transparency; • Comparison of the offers/alternative ship designs; • Control of suppliers already in the bidding phase by critically questioning the LCC data; • Basis for tender award.
2 Vehicle	• Structured distribution of the LCC information in a fixed CBS; • LCC information requests on four primary cost elements: procurement, staff/training, logistics, and infrastructure.	• Identification of the main cost drivers in the project; • Creation of cost transparency; • Standardized instrument for the structured consolidation of all costs incurred by the system.	• Commissioning of an external company for the LCC estimation; • Specification of the pursued objective; • Specification of the CBS; • Predominantly manual entry and merging of the necessary LCC information.	• External support for LCC estimation; • External support for developing a LCC database; • External support for developing a LCC simulation model.	• Little existing LCC skills in the project team; • One team member that was already part of LCC estimation of a different vehicle; • The focus was on coordination and quality assurance.	• Available data (such as life support analysis) were not sufficient to enable a valid LCC estimation; • Development of a simulation for LCC estimation; • Comparison of the simulated LCCs with expert estimations.	• Creation of cost transparency; • Decisions about budget planning for system upgrades.

3 Jet	• Structured distribution of the LCC information in a fixed CBS; • LCC information requests on four primary cost elements: procurement, staff/training, logistics, and infrastructure; • Different LCC information requests per management level (Parliament vs. project).	• Creation of the possibility to provide information to Parliament; • Creation of cost transparency; • Identification of the main cost drivers in the project.	• Commissioning of an external company for the LCC estimation; • Specification of the pursued objective; • Specification of the CBS.	• External support for LCC estimation; • External support for developing a LCC database.	• No existing LCC skills in the project team at the beginning; • Building the knowledge through collaboration with supplier.	• Comparison of LCC estimation with cost information from different jets.	• Creation of cost transparency; • (Long-term) capability planning; • Decision about the technical solution; • Decision about maintenance, repair, and overhaul concepts and cycles; • Decisions about Budget Planning in the future.
4 Train	• LCC of the trains, with strong focus on cost drivers, e.g., power consumption, maintenance and cleaning services, and manpower requirements; • LCC target corridor for suppliers.	• Award of the procurement project taking LCC information into account; • Long-term cost transparency; • Identification of the main cost drivers in the project; • Basis for a contractual fixation of the designated LCC of the manufacturers.	• Award of the procurement project taking LCC information into account; • Long-term cost transparency; • Identification of the main cost drivers in the project; • Basis for a contractual fixation of the designated LCC.	• Specification of framework parameters for bidders (maximum speed, number of seats, etc.); • Specification of a planned usage profile for the trains; • Specification of an LCC target corridor for the bidders.	• LCC estimations provided by the offers; • Validation of the LCC estimations by an external consultant.	• Commissioning of an external company for review of the LCC estimation.	• LCC as key tender requirement; • Regular review of the LCC in the utilization phase; • Contractual fixing of LCC for the identified cost drivers (e.g., power consumption, maintenance, and services).
5 Rail	• Availability and sustainability as the top target criterion of the acquisition project;	• Award of the procurement project taking LCC information into account;	• Specification of the framework conditions for the use of the fleet;	• LCC estimations provided by the suppliers in the offers.	• In-house know-how, especially for the commercial calculation	• Comparison of the LCC estimation with already-	• Energy consumption identified as main cost driver and,

	• LCC estimation for the procurement project as a whole, as well as LCC estimations for the operation of the train fleet.	• Long-term cost transparency; • Identification of the main cost drivers in the project; • Basis for a contractual fixation of the designated LCC of the manufacturers.	• Estimation of the LCC by the supplier and indication in the offers; • Separation of LCC estimation in procurement and operation because of different responsibilities.		of the acquisition project available; • No special LCC estimation know-how available.	implemented acquisition projects.	therefore, separately contractually fixed; • Measurement of energy consumption on a test track and regular review agreed upon; • LCC as an award criterion.
6 Tramway	• Focus for LCC estimation primarily on procurement and fleet maintenance costs; • Consideration of existing maintenance infrastructure (LCC as information but not to be negotiated).	• Decision-making basis for the economic procurement of a new fleet; • Long-term cost transparency; • Long-term commitment to the contractually fixed maintenance prices; • Definition of target values, which are contractually fixed.	No specific insights gained from the interview.	• LCC estimations provided by the suppliers in the offers.	• No special LCC estimation know-how available.	• Only consideration of the presumed maintenance costs of the fleet. Here, a comparison with empirical values of past projects. No LCC available before.	• The focus of the LCC estimation is on the control of maintenance and repair measures, as these have been identified as the main cost drivers.
7 Building	• Costs are divided into procurement costs and the costs of operation; • Utilization profiles as an additional criterion, which are assigned with LCC estimation.	• Support in the evaluation of the most economical procurement option (e.g., PPP vs. 100% outsourcing); • LCC estimation as a basis for contracting service-level agreements.	• Specification of the LCC objective and life cycle; • Definition of alternative solutions to be tested; • Specification of the most important performance parameters (e.g., building availability); • Execution of the LCC estimation.	• LCC estimations provided by external consulting offices; • Support for LCC estimations by banks.	• In-house know-how, especially for the commercial calculation; • Know-how available for the comparison of different forms of financing; • LCC estimation based on MS Excel.	• Comparison of the LCC estimation with already-implemented acquisition projects.	• LCC estimations as a tool for comparing alternatives; • LCC estimation for contractual fixation and supplier management through SLAs.

8 Highway	• Cost information for using different construction materials.	• Evaluation of the (long-term) economic viability; • Control tool for a cost comparison at the beginning and at the end of the project; • Instrument for selection decision of the most economical solution.	• Predefined sets of rules for the LCC estimation; • LCC estimation is carried out in two steps: before the invitation to tender and again before the award decision (comparison of offers).	• Extensive set of rules for LCC estimations in-house available; • No existing database available, using MS Excel Sheets.	• Experts for cost estimations and for calculating different cost scenarios available in-house.	• Use of internal rules and regulations for the calculation of LCC. Validation of the predicted LCC with the help of field data from projects already carried out.	• Consideration of infrastructure measures over the entire life cycle and not just by year/available budget.
Cross-case observations	• ES LCC information request depends on management level; • Cost breakdown for system vs. subsystem vs. part; • Case-by-case-only consideration of the main cost drivers.	• Identification of the main cost drivers; • Getting cost transparency; • ES LCC as tender criteria; • ES LCC as information and decision support instrument; • Increasing sustainability by using ES LCC.	• ES LCC estimation by own resources; • Internal ES LCC competence center; • ES LCC estimation by external consultants; • ES LCC estimation by the supplier.	• ES LCC estimation based on MS Excel; • Specialized tools for ES LCC estimation, such as 4Cost Aces, Systecon Opus Suite; • Support by external consultants or banks.	• Varies widely from extensive ES LCC know-how available to little or no existing ES LCC know-how available; • In-house cost competence center exists.	• Validation of ES LCC estimation by application of simulation; • Comparison of the ES LCC estimation with comparable projects.	• ES LCC estimations as tender/award criteria; • ES LCC for comparison of alternatives; • ES LCC estimations for budget planning and asset management; • ES LCC estimation for contractual fixation.

Generally, we can observe throughout all the cases that ES LCC information processing is also quite homogenous, or at least more homogenous, as one might expect. The granularity of the information requirements usually go deeper than the system to subsystem or main cost driver level. Required information aims to lever transparency and to enable the identification of critical cost drivers. Furthermore, BCs typically lack, or have limited, ES LCC capability, but are supported by centralized and more specialized LCC departments or receive external (consultancy) support. Tooling in terms of software is available on the market in a wide variety of products. Finally, BCs perceive their ES LCC information as sufficient, but lack experience from other or previous projects to really evaluate their own work (lack of benchmark). ES LCC is sufficient to support the comparison of alternatives (in development phases), to evaluate suppliers by tender/award criteria, to plan and budget strategic assets, and finally to contract suppliers with LCC cost lines. Generally, the cases all show that they use ES information for their procurement decision making.

5. Discussion and Implications

This research analyzes how sustainability could be assessed with the means of a cost-benefit analysis and focuses on LCC as an instrument and the economic dimension of sustainability. The work merges theory from OIPT with OBB in order to better understand how the information processing of an ES LCC can result in better procurement decisions. A remarkable point is that ES LCC information is usually based on estimations, which makes the data biased by forecasting errors. For the procurement decision, this means that an offer must be chosen under ES LCC uncertainty (see decision theory, e.g., reference [83]). Therefore, it is important to know how members of the BC assess and process ES LCC information [84]. Within the BC, more or less informed participants might influence the decision, as well as BC participants who have varying levels of understanding of ES LCC information [85].

This study is able to show that managerial practice in the cases considers ES LCC as a relevant information requirement. Furthermore, the LCC bears the potential to become a kind of standard to assess ES, because the LCC information requirements in almost every case were quite similar. The information requirements do not stop at LCC for the overall system, but usually go deeper into subsystem levels. The reasons for carrying out LCC estimations are also comparable in all cases: they mainly serve to create cost transparency in the investigated projects [35,86]. Besides this, each project contributes to experience building and long-term learning. Finally, LCC information is required in order to support the evaluation of offers. By doing so, LCC information guides the contracting authority to choose the most economically advantageous offer; here that means the most ES solution [42].

It is also interesting to observe which ES LCC information processing capabilities exist in the BC [87]. These capabilities vary greatly. In some cases, the projects are obliged by the regulations of the procurement authority to record LCC. Thus, LCC is executed by specific departments while the BC of the project has no capability of its own. In other cases, know-how is available within the BC. For example, the German Defense Procurement Authority has its own CCC that supports the LCC estimation. However, such a central department is not equipped for the permanent support of a multitude of projects. This is why we observe a stepwise approach: First, we see BCs with their own ES LCC capabilities. Then, there are BCs that are supported by in-house, specialized LCC-capable departments. Third, there is often external (consultancy) support if capabilities are not sufficient [12]. However, we could observe that all cases had a structured process for conducting LCC estimations, even if the processes differed according to the project under consideration. In all cases, capabilities for considering ES LCC were in place (internal or external). Even if these were in some cases bottlenecks and required external support, the BC was able to obtain and process ES LCC information.

Lastly, we refer to the information processing fit assessment. Here, we observe that ES LCC information is supporting procurement as tender/award criteria, for comparison of alternatives, for budget planning, and strategic asset management, as well as for contractual fixation and incentive systems [42,88]. As such, we can positively interpret this aspect as a good balance between information requirement and information capability, because ES LCC information is appropriately processed. However, there are cases in which BC participants claim that a better validation of ES LCC estimations would be helpful. The capability to access other and previous project data is mentioned in this context [89]. For example, in the case of Highway AG, information from past projects is available, which is used for an evaluation (analogy method). However, the use of this data is not easily possible because there is no standardized solution for storing and processing the data. In the defense sector, the number of available reference projects is limited. A practical recommendation coming from Case 2 is to build up a database as a tool for collecting, evaluating, and assessing ES LCC information. These findings are consistent with, among others, the studies of Korpi and Ala-Risku (2008) [35].

For the initial RQ, we are able to state that for assessing ES, the tool of LCC is appropriate and, due to its implementation in practice, already a mature instrument. Referring to RQ1, we observe that BCs not only require an ES LCC analysis on a system level, but also on a subsystem or cost driver level. As such, the key information requirement is a fine-grained ES LCC information structure. Referring to RQ2, the cases indicate that there is a stepwise information demand. We could identify that BC members with high decision power (e.g., decider, Parliament, and strategic management) required, or received, aggregated ES LCC information in order to manage procurement decisions at a higher and aggregated level. Other members of the BC (influencer, buyer) aim to have utmost transparency, at least to subsystem level, in order to consider all technical and cost requirements. These findings can also be supported by additional sources besides the cases. In the defense sector, for example, it was possible to evaluate additional documents containing ES LCC information for top management and the political level. This information is highly condensed in the evaluated documents and only partially reproduced. The comprehensive creation of cost transparency at the level of the main cost elements is thus not achieved. This makes an evaluation at the strategic level more difficult and supports decision making in procurement only to a limited extent.

We were not able to fully assess how gatekeepers (e.g., specialized LCC departments or external LCC consultancies) use their ability to share or not to share ES LCC information and how this is influencing the BC. Uncertainty about forecast bias might cause reluctancy to share information, while on the other hand, BC participants called for permanent ES LCC information. Therefore, we observe indications for potential misalignments or information asymmetries within a BC if information processing is not governed correctly. Finally, we refer to RQ3 and can state that ES LCC is not a "white elephant", but had impact on procurement as tender/award criteria, for the comparison of alternatives, for budget planning, and strategic asset management, as well as for contractual fixation and incentive systems. This is a positive signal, because then ES is considered in the procurement decision. As a practical implication, this would call for building up ES LCC capabilities, at least when procuring high-value investment goods with long life cycles. Propositions and recommendations for action in relation to IPT and OBB/BC can be derived from previously discussed findings (see Table 2).

Table 2. Proposition and recommendation matrix.

	RQ1 Which LCC Information is Gathered and Reported?	RQ2 Which BC Members Need Which LCC Information at What Time?	RQ3 Which Decisions of the BC are Influenced by LCC Information?
IPT	• Appropriate ES LCC information processing capabilities are required to identify information needs; • The design depends on the organization size: • Large organizations: LCC competencies can be built up in-house; • Small organizations: Situational capability (use of LCC service providers is recommended).	• Determination of information requirements per management level; • Definition of responsibilities, e.g., who is responsible for obtaining which kind of ES LCC information and how they have to be processed and reported; • Ensuring a stepwise and continuous ES LCC information distribution.	• ES LCC information influences all major project decisions, including budget planning, strategic asset management, and the application of incentive systems; • ES LCC information allows strategic (cross-project) control; • The analysis of LCC cost drivers can influence the selection of controlling objectives (KPIs).
OBB/BC	• ES LCC information should be gathered in a standardized information structure following a fine-grained CBS; • Costs for development, design, production, operation, upgrades during the life cycle, and disposal are required.	• ES LCC information needs depend on the hierarchy level: • Top-level BC members require highly aggregated data; • Lower-level BC members require the utmost degree of detail; • Top-level BC members require ES LCC information before the procurement decision; lower hierarchy BC members require permanent ES LCC information.	• ES LCC information de facto influences all BC decisions: e.g., on tender/award criteria, comparison of alternatives, (long-term) control of cost drivers, contractual fixation, and the definition of procurement strategy; • In order to ensure the comparability of several offers, a realistic (product) utilization profile is required.

Finally, we want to state that politics and society call for the achievement of a higher level of sustainability. The cases show that LCC is an instrument that operationalizes this high-level goal into specific cost figures and fine-grained CBS. This helps to consider not only social or ecological sustainability goals but also addresses hitherto insufficiently regarded economic sustainability goals. The use of LCC as award criteria is clearly stipulated by procurement legislation. In addition, public contracting authorities can create the managerial conditions to be able to apply ES LCC as a strategic management tool. To this end, they must, for example, build up the skills and capabilities of purchasers so that they are able to use ES LCC as an evaluation and decision-making tool.

Furthermore, prerequisites must be created for market participants so that they can perform a calculation of LCC. To this end, for example, the calculation methods and evaluation criteria must be made known to potential bidders by the contracting authorities.

In the cases, different possibilities for creating the framework conditions have been presented.

6. Conclusions and Limitations

Numerous ecologic, social, and economic signals point to the need to increase sustainability. However, the measurement of sustainability is not only limited to carbon footprint- or child-labor-monitoring systems. Our research showed that LCC is able to measure a product/project in a holistic way, even though aspects such as carbon footprint can be calculated as part of LCC, e.g., by taking the cost of CO2 emissions during production and use phases as part of the cost breakdown structure. LCC not only distinguishes cost elements and cost drivers, but is also provoking us to think of alternatives. LCC tries to identify cause–effects, e.g., how the initial prices of today affect operating costs in the future. This is what we call the "LCC-optimization-rational", which is—like sustainability—connecting current decisions with the ability to prosper in the future.

Therefore, LCC might guide procurement boards to make better—more economically sustainable—decisions. Our research supports the need for efficient and effective ES LCC information distribution. It seems rather obvious that decision makers require the correct information to factor sustainable alternatives into their decision making. The cases showed that it is possible to use LCC not only as a cost control and monitoring system, but as an ES information source. It helps public sector authorities to evaluate the impact of procurement decisions before tendering. This is performed, for example, by taking the utilization costs of long-life capital goods associated with the procurement decision into account. This enables public-sector authorities to adjust their budget planning for the coming years and thus make economically sensible procurement decisions. This, in turn, establishes a clear link to the regulations in the Public Procurement Act because the most economically advantageous tender can be selected.

Therefore, this research could guide theory and practice, as our findings point to the need for better information processing. Our paper merges organizational information processing theory and organizational buying behavior theory in a novel way. Future research could further elaborate ES LCC processing on that basis.

Finally, we are aware that the qualitative, case-based approach of our study faces the typical empirical limitations. Nevertheless, the mix of cross-case analysis with embedded units of analysis balances the case settings. Our case informants are also from a high management level and typically represent the decision maker in the buying center. Furthermore, the research used the triangulation of data and two researchers cross-validated data and interviews. Therefore, we see empirical limitations (German context and focus on the procurement side) but are confident that we have a reliable and valid set of data as a basis for our implications. Of this data, the most relevant for us was the fact that decision makers are keen to acquire the "right" information. They want to make sustainable decisions, but often lack suitable information. LCC could close that gap.

Author Contributions: Conceptualization, J.G., S.W. and A.H.G.; Investigation J.G. and S.W.; Methodology, J.G. and S.W.; Project administration, A.H.G.; Supervision, A.H.G. and M.E.; Visualization, A.H.G.; Writing – original draft, J.G., S.W. and A.H.G.; Writing – review & editing, A.H.G. and M.E. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement:

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement:

Conflicts of Interest: The authors declare no conflict of interest.

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