Development of a Process for Improved Integration of Environmental Cost Indicator in Construction Projects

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I. Preface

Presented before you is the thesis titled 'Development of a Process for Improved Integration of Environmental Cost Indicator in Construction Projects'. This report includes the methodology and the results of a research conducted to obtain the Master of Science (MSc) degree in Civil Engineering & Management at the University of Twente in Enschede, The Netherlands.

The inception of this research can be attributed to Mobilis TBI, who commissioned and supported this project. As an integral part of the TBI Holding, Mobilis TBI actively engages in infrastructure projects of diverse scales, placing an emphasis on civil engineering. Their commitment to advancing knowledge and enhancing the sustainability of infrastructure projects led to the commissioning of this research. The outcomes are applied to structure the environmental cost indicator, aligning with Mobilis TBI's goal to improve the sustainability of their infrastructure projects.

My personal motivation for this research comes from a profound interest in optimizing sustainability aspects within civil engineering while merging various aspects of the discipline. Mobilis TBI has provided a platform for me to explore a research area where my interests in civil engineering align with practical applications. For this, I express my gratitude for the granted opportunity. I extend my appreciation to my supervisors from both Mobilis TBI and the University of Twente for their guidance, criticism, and support throughout this research. Their combined knowledge has played a pivotal role in shaping this research. Also, I would like to thank my close family, friends, and roommates for their support and encouragement, guiding me through the challenges encountered during this research.

As you read this thesis, I hope you find both inspiration and practical insights in this work and let it contribute to improving the practical implementation of sustainability practices in infrastructure projects to create a more sustainable and resilient future.

II. Summary

Background Information

With the AEC sector being a major contributor to greenhouse gas emissions and resource depletion, Dutch Governmental agencies have embraced sustainability initiatives to mitigate the environmental impact of infrastructure projects. A major initiative is the integration of the Milieu Kosten Indicator (MKI) into tender biddings which serves as a standardized approach to quantifying the environmental impact of projects. Mobilis TBI, a Dutch contractor, is obligated to calculate the MKI when submitting bids for projects initiated by Dutch governmental agencies. Given this requirement, there is a need to refine this process to improve the construction of more environmentally friendly projects.

Research Goal

This research focuses on addressing challenges at Mobilis TBI regarding the integration of MKI calculations into their projects. Mobilis TBI frequently collaborates with government agencies such as Rijkswaterstaat, ProRail, and provinces, which have increased the use of MKI during the tendering phase. Consequently, it becomes increasingly important for contractors like Mobilis TBI to optimize MKI calculations. Currently, Mobilis TBI lacks a standardized process for MKI integration, leading to issues such as design choices without sufficient MKI awareness, non-standardized processes causing errors, and irregular updates of MKI calculations. This has resulted in non-compliance with contract requirements and fines imposed on the company.

To address these challenges, Mobilis TBI aims to establish a standardized process for MKI integration in all future projects. This process should clearly define tasks and responsibilities for each phase, ensuring effectiveness, efficiency, and alignment with other business processes. The anticipated benefits include increased MKI awareness during the design process, a reduction in errors, and consistent attention to MKI throughout the construction processes. Ultimately, the goal is to decrease fines, increase the likelihood of winning tenders, meet customer expectations, and realize more environmentally friendly projects.

Method

The methodological approach employed in this research adheres to the Design Science Research Methodology (DSRM), a structured framework comprising six key activities arranged in a sequential order. The DSRM serves as a systematic guide for researchers undertaking Design Science Research (DSR) and unfolds through the following activities: problem identification, objective definition, design and development, demonstration, evaluation, and communication. The adoption of the DSRM is chosen because of its proven effectiveness in addressing organizational challenges through the systematic design and development of artifacts, thereby contributing to advancements in research.

Problem Identification and Objective Definition

The first phase of this research focused on the problem identification. During this activity, the essential aspects, and issues of the current MKI calculation process were identified. Three different data sources, namely academic literature, project documentation, and expert interviews, were used to conduct a thorough problem identification. Through a systematic approach employing line-by-line coding, a profound understanding of the identified problems was gained. In the first focus group, consisting of five internal experts at Mobilis, these problems were validated. Based on this in-depth analysis, the experts identified 11 specific problems, which were then systematically placed within the Sustainable Project Management (SPM) framework.

The subsequent activity aimed at formulating objectives for the new MKI process at Mobilis TBI. The identified problems were translated into design principles according to the framework of Chandra et

al. (2015). These design principles are crucial for making thoughtful design choices for the new process and were validated and prioritized in a second focus group. This step has laid a solid foundation for the further development of the new MKI process.

Design & Development

The third activity involved creating the artifact of this research in the form of the new MKI process. This creation process was guided by the design principles established during the second activity. These principles shape the architecture and characteristics of the process, translating these into concrete design features. Insights from interviews and focus groups play a key role in ensuring the new process aligns with real-world needs. The Sensus Methodology is adopted for process modeling, providing a standardized and consistent approach. The design of the process model in Sensus Method prioritizes user comprehension. It uses eight clear icon types, following conventions for placement and usage. This systematic method for process modelling ensures effective process management.

Demonstration, Evaluation, and Communication

The newly designed process was presented and validated during the fourth activity in the third focus group. Issues identified by the experts with the new process were addressed directly. The fifth activity involved evaluating the designed artifact. During the third focus group, experts assessed whether the identified problems were addressed using the newly designed MKI process. The final activity included detailed documentation of results in this thesis and an implementation plan for Mobilis TBI, highlighting the practical application of the new process.

Conclusion and Recommendations

Through thorough analysis of the existing problems and collaboration with experts, two robust processes were developed aimed at resolving the identified problems. This process is especially effective in addressing the challenges in the corporate policies category of the SPM framework. For the problems of the other categories of the SPM framework further research and refinement is necessary for further improvement of the measurement of sustainability. By comprehensively addressing every aspect of sustainable project management concerning sustainability measurement, sustainability efforts within infrastructure projects can be advanced. Furthermore, it is crucial for Mobilis TBI to prioritize the implementation of these processes and thereafter to validate the findings of this research across diverse organizational contexts.

III. Samenvatting

Achtergrond Informatie

Met de AEC-sector als een belangrijke bijdrager aan de uitstoot van broeikasgassen en uitputting van natuurlijke materialen, hebben Nederlandse overheidsinstanties duurzaamheidsinitiatieven omarmd om de milieueffecten van infrastructurele projecten te verminderen. Een belangrijk initiatief is de integratie van de Milieu Kosten Indicator (MKI) in aanbestedingen, wat dient als een gestandaardiseerde benadering om de milieueffecten van projecten te kwantificeren. Mobilis TBI, een Nederlandse aannemer, is verplicht de MKI te berekenen bij het indienen van biedingen voor projecten die zijn geïnitieerd door Nederlandse overheidsinstanties. Gezien deze verplichting is er behoefte aan verbetering van dit proces om de constructie van milieuvriendelijkere projecten te bevorderen.

Onderzoeksdoel

Dit onderzoek richt zich op het aanpakken van uitdagingen bij Mobilis TBI met betrekking tot de integratie van MKI-berekeningen in hun projecten. Mobilis TBI werkt vaak samen met overheidsinstanties zoals Rijkswaterstaat, ProRail en provincies, die het gebruik van MKI tijdens de aanbestedingsfase hebben verhoogd. Hierdoor wordt het steeds belangrijker voor aannemers zoals Mobilis TBI om MKI-berekeningen te optimaliseren. Momenteel ontbreekt het Mobilis TBI aan een gestandaardiseerd proces voor MKI-integratie, wat leidt tot problemen zoals ontwerpkeuzes zonder voldoende MKI-bewustzijn, niet-gestandaardiseerde processen die fouten veroorzaken en onregelmatige updates van MKI-berekeningen. Dit heeft geresulteerd in het niet voldoen aan contractvereisten en opgelegde boetes aan het bedrijf.

Om deze uitdagingen aan te pakken, streeft Mobilis TBI naar de oprichting van een gestandaardiseerd proces voor MKI-integratie in alle toekomstige projecten. Dit proces moet taken en verantwoordelijkheden voor elke fase duidelijk definiëren, zodat effectiviteit, efficiëntie en afstemming met andere bedrijfsprocessen worden gewaarborgd. De beoogde voordelen zijn onder andere verhoogd MKI-bewustzijn tijdens het ontwerpproces, een afname van fouten en consistente aandacht voor MKI gedurende de bouwprocessen. Uiteindelijk is het doel om boetes te verminderen, de kans op het winnen van aanbestedingen te vergroten, aan de verwachtingen van de klant te voldoen en meer milieuvriendelijke projecten te realiseren.

Methode

De methodologische aanpak die in dit onderzoek wordt gebruikt, volgt de Design Science Research Methodology (DSRM), een gestructureerd raamwerk bestaande uit zes kernactiviteiten gerangschikt in een opeenvolgende volgorde. De DSRM fungeert als een systematische gids voor onderzoekers die Design Science Research (DSR) uitvoeren en ontvouwt zich via de volgende activiteiten: probleem identificatie, doelstelling definitie, ontwerp en ontwikkeling, demonstratie, evaluatie en communicatie. De keuze voor de adoptie van de DSRM is gebaseerd op zijn bewezen effectiviteit bij het aanpakken van organisatorische uitdagingen door het systematische ontwerp en de ontwikkeling van artefacten, wat bijdraagt aan vooruitgang in onderzoek.

Probleem Identificatie en Doelstelling Definitie

De eerste fase van dit onderzoek betrof de probleemidentificatie. Tijdens deze activiteit zijn de essentiële aspecten en problemen van het huidige MKI-berekeningsproces geïdentificeerd. Drie verschillende databronnen, namelijk academische literatuur, projectdocumentatie en expertinterviews zijn gebruikt om tot een grondige probleem identificatie te komen. Via een systematische benadering met line-by-line codering is een diepgaand inzicht verkregen in de

geïdentificeerde problemen. In de eerste focusgroep, bestaande uit vijf interne experts bij Mobilis, zijn deze problemen gevalideerd en geprioriteerd. Op basis van deze diepgaande analyse hebben de experts 11 specifieke problemen geïdentificeerd, die vervolgens systematisch zijn geplaatst binnen het kader van Sustainable Project Management (SPM) framework.

De volgende activiteit richtte zich op het formuleren van doelstellingen voor het nieuwe MKI-proces van Mobilis TBI. De geïdentificeerde problemen zijn vertaald naar ontwerpprincipes volgens het raamwerk van Chandra et al. (2015). Deze ontwerpprincipes zijn cruciaal voor het maken van doordachte ontwerpkeuzes voor het nieuwe proces en zijn gevalideerd en geprioriteerd in een tweede focusgroep. Deze stap heeft een solide basis gelegd voor de verdere ontwikkeling van het nieuwe MKI-proces.

Ontwerp en Ontwikkeling

De derde activiteit omvatte het creëren van het artefact van dit onderzoek in de vorm van het nieuwe MKI-proces. Dit creatieproces werd geleid door de ontwerpprincipes die tijdens de tweede activiteit waren vastgesteld. Deze principes vormen de architectuur en kenmerken van het proces, resulterend in concrete ontwerpelementen. Inzichten uit interviews en focusgroepen spelen een cruciale rol om ervoor te zorgen dat het nieuwe proces aansluit bij de behoeften in de praktijk. De Sensus-methodologie wordt toegepast voor procesmodellering, waardoor een gestandaardiseerde en consistente aanpak wordt geboden. Het ontwerp van het procesmodel in de Sensus-methodologie heeft gebruikersbegrip als prioriteit. Het maakt gebruik van acht duidelijke iconen en volgt conventies voor plaatsing en gebruik. Deze systematische methode voor procesmodellering waarborgt effectief procesbeheer.

Demonstratie, Evaluatie en Communicatie

Het nieuw ontworpen proces werd gedurende de vierde activiteit gepresenteerd en gevalideerd tijdens de derde focusgroep. Problemen die werden gezien door de experts met het nieuwe proces zijn direct verholpen. De vijfde activiteit is de evaluatie van het ontworpen artefact. Tijdens de derde focus groep hebben de experts geëvalueerd of de geïdentificeerde problemen zijn verholpen aan de hand van het nieuw ontworpen MKI-proces. De laatste activiteit omvatte een gedetailleerde documentatie van resultaten in deze thesis en een implementatieplan voor Mobilis TBI, waarbij de praktische toepassing van het nieuwe proces wordt uitgelicht.

Conclusie en Aanbevelingen

Door middel van grondige analyse en samenwerking met experts werden twee robuuste processen ontwikkeld, waarbij voornamelijk uitdagingen op het gebied van bedrijfsbeleid duidelijk aanwezig waren en daarbij werden verholpen. Dit proces is vooral effectief in het aanpakken van de uitdagingen in de categorie bedrijfsbeleid van het SPM-framework. Voor de problemen van de andere categorieën van het SPM-framework is verder onderzoek en verfijning nodig voor verdere verbetering van de meting van duurzaamheid. Door elk facet van duurzaam projectmanagement uitgebreid aan te pakken met betrekking tot het meten van duurzaamheid, kunnen duurzaamheidsinspanningen binnen infrastructurele projecten worden bevorderd. Voor Mobilis TBI is het van cruciaal belang om de implementatie van deze processen te prioriteren en vervolgens de bevindingen van dit onderzoek te valideren in verschillende organisatorische contexten.

IV. Table of Contents

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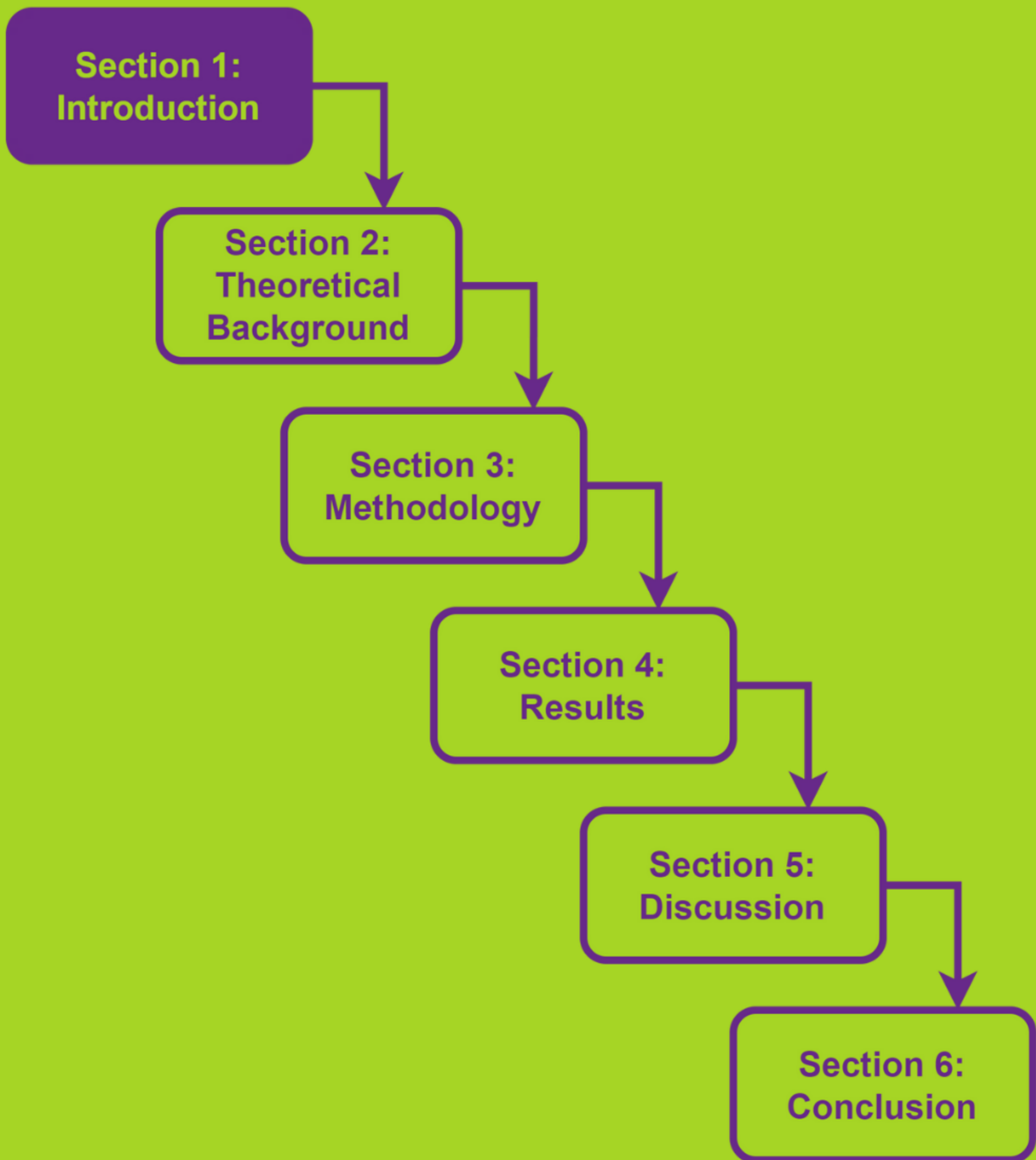
VII. List of Acronyms

AEC	Architecture, Engineering and Construction
LCA	Life Cycle Analysis
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Analysis
MKI	Milieu Kosten Indicator
DuBoCalc	Duurzaam Bouwen Calculator
NMD	Nationale Milieu Database
PMBOK	Project Management Body of Knowledge
BIM	Building Information Modelling
SPM	Sustainable Project Management
DSRM	Design Science Research Method

This Section offers a comprehensive insight into the global importance of the sustainability goals and the influence that the construction industry has in achieving these goals. The narrative then contextualizes the research by detailing the establishment of the Milieu Kosten Indicator (MKI) by Dutch governmental agencies, with a specific focus on the challenges encountered in these calculations by the Dutch contractor, Mobilis TBI. Moreover, the Section states the goal of this research.



INTRODUCTION

1 Introduction

In 2015, the United Nations established the 2030 Agenda for Sustainable Development, which includes 17 sustainable development goals (United Nations, 2015). Despite global progress, more steps are necessary to achieve these goals (United Nations, 2019). The Architecture, Engineering, and Construction (AEC) sector, a major contributor to greenhouse gas emissions and resource depletion, plays a crucial role in achieving the sustainability goals. This sector alone is responsible for 40% of global energy use and greenhouse gas emissions, and almost one-third of global resource consumption (Carvalho et al., 2019; Rode et al., 2011). Therefore, increased implementation of sustainable practices is crucial for achieving the sustainability goals.

To reduce the environmental impact of the AEC sector significant sustainability research has been conducted. Mavi et al. (2021) conducted a literature review on critical research directions in sustainability, identifying areas that need further investigation. Important research directions include the development of new environment friendly materials (Guo et al., 2020; Mohamed et al., 2021), reducing waste and hereby the environmental impact by using the principles of lean construction (Ogunbiyi et al., 2014), innovative construction methods such as modular construction to reduce energy and resources used during construction (Abdul Nabi & El-adaway, 2020; Musa et al., 2014; Turner et al., 2021), and circularity, aiming on creating a closed-loop system continuously reusing and repurposing materials to enhance resource efficiency and minimize waste (Anastasiades et al., 2020; Ghaffar et al., 2020; Martek et al., 2020). Another critical identified research area by Mavi et al. (2021) in sustainability is the development of a single or dominant system to evaluate sustainability in AEC projects. This would make sustainability evaluation as common as risk assessment and mitigation, increasing the feasibility of incorporating sustainable practices in projects. Currently, several systems for evaluating sustainability exist, such as BREEAM and LEED (Awadh, 2017; Fewings & Henjewele, 2019). A final research area is sustainability measurement, which includes tools such as Life Cycle Assessments (LCA) that assess the environmental impact of building material throughout its lifecycle. These research directions are essential in enhancing the AEC sector's sustainability and promoting a more sustainable future (Kristen & Mikhail, 2014).

This research focuses on the Netherlands, where most infrastructure is managed by governmental agencies, who play a crucial role in impacting the environment in the Netherlands by maintaining and developing the infrastructure. Due to this impact on sustainability, these agencies are dedicated to sustainable development. For example, Rijkswaterstaat encourages contractors to innovate in sustainable solutions by issuing non-specific calls for proposals and to allow contractors to test and legitimize new innovations in the GWW sector (Rijkswaterstaat, 2023). Similar to Rijkswaterstaat, ProRail collaborates with contractors to innovate, leading to the adoption of sustainable materials and systems (ProRail, 2023; van Ee, 2020). Most commonly, Dutch government agencies integrate sustainability into projects using the Milieu Kosten Indicator (MKI, or Environmental Costs Indicator) as a criterion for awarding tenders. The MKI is a standardized method of comparing the environmental impact of products or projects throughout their lifecycle. This MKI is calculated using a LCA tool called DuboCalc (Duurzaam Bouwen Calculator, or Sustainable Building Calculator) (Pianoo, 2020). This method is regularly used and steadily rising as an award criterion during tenders for infrastructure projects (Olde Monnikhof & Ubink, 2021). Using MKI during construction projects is vital for promoting sustainability in the Netherlands as it allows for a standardized measurement of the environmental impact of infrastructure projects. By measuring sustainability, the MKI enables clients to give preference to contractors who work sustainable. Consequently, the goal of Dutch agencies is to incentivize contractors to adopt and invest in sustainable practices. This reasoning is supported by the research of Mavi et al. (2021), which highlights the importance of using standardized sustainability measuring methods, to progress towards the 2030 sustainability goals.

The problem owner of this research, Mobilis TBI, is a contractor which specializes in infrastructure projects in the Netherlands, such as bridges, tunnels, parking garages, and purification plants. In these projects, the aim is to deliver high-quality construction meeting client requirements and goals. In many of these projects the government is the client, and they increased their use of the MKI during tendering. As a result, contractors such as Mobilis TBI are also required to work with the MKI. In addition, Mobilis TBI aims to incorporate MKI calculations in all their projects. Mobilis TBI has worked on several projects which included an MKI component (Rook et al., 2022). Currently, Mobilis TBI has a general process for MKI in their projects, which is not universally applicable to all projects and phases. As a result, each project had to create a its own methods for MKI calculations, distributing tasks and responsibilities in the project team. Mobilis TBI's current approach led to issues, including low employee awareness of MKI in design choices, unexecuted supporting tasks due to lack of standardization, and infrequent updates to the calculation. Due to these and other issues, Mobilis TBI failed to meet contract requirements, resulting in fines to the client as the basis on which the project was awarded could no longer be achieved.

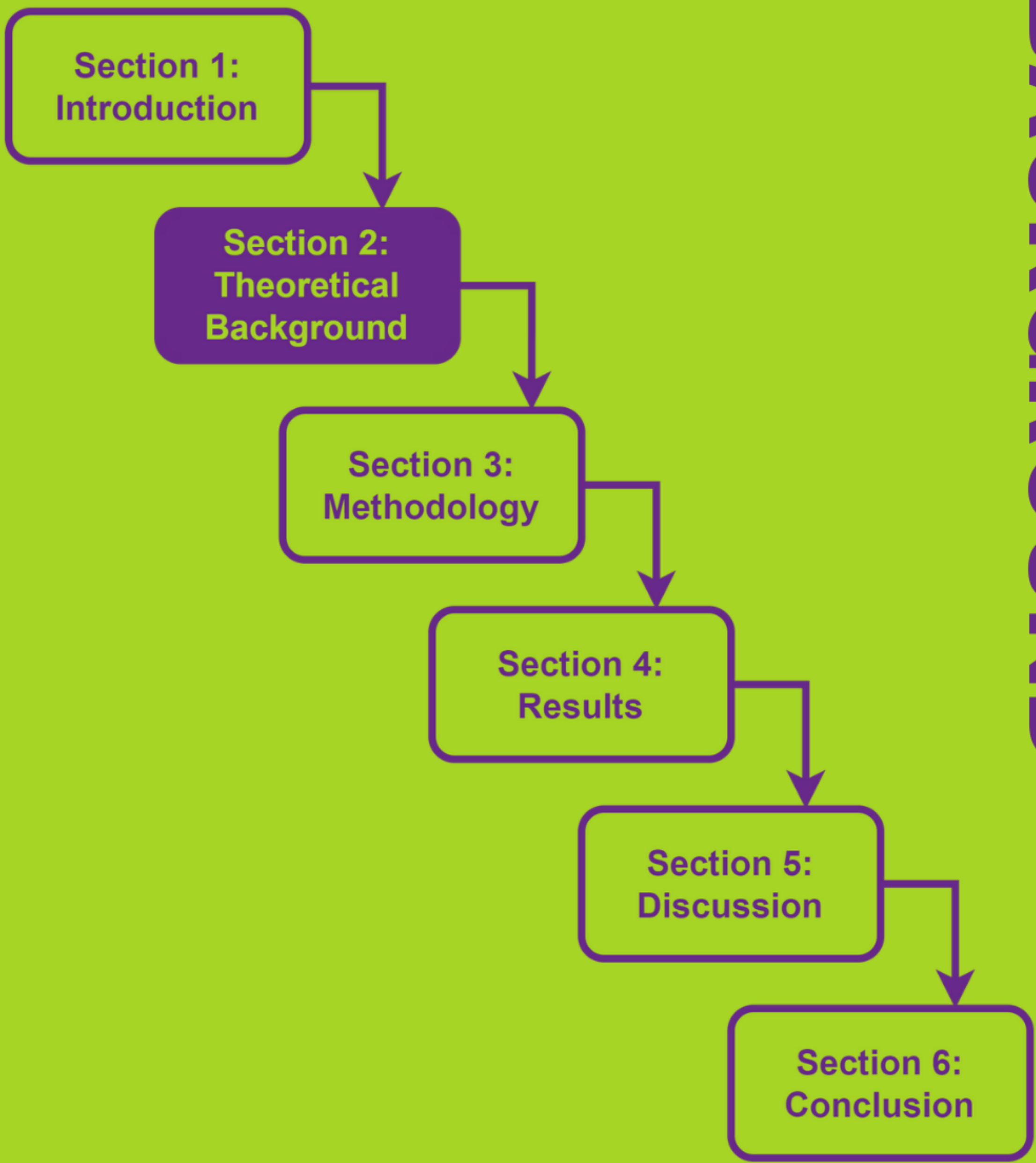
To address these issues, Mobilis TBI has indicated that it would like to have a standardized process for incorporating the MKI and use it for all their future projects. This standardized process should be able to indicate clearly to all involved employees what tasks should be fulfilled during which phase and in which order. By creating and implementing this process the company hopes to achieve several benefits. Firstly, by standardizing the process, employees will be more aware of the MKI during the design process and how their choices affect the MKI of the project. Secondly, a more structured process decreases the number of mistakes regarding the MKI. Finally, by including the MKI-calculations consistently in the construction processes of Mobilis TBI, the MKI will be considered throughout choices during the project which will increase control of the MKI-value. These benefits would ultimately contribute to the overall goals of the process, which are reducing fines paid to clients, increasing the chances of winning more tenders, fulfilling the wishes of the clients, and being able to create more environmentally friendly projects. As mentioned, the current MKI process at Mobilis TBI is too general and not universally applicable. Furthermore, the current MKI process is incompatible with other processes, risking conflicting actions, such as an incorrect order of steps. Therefore, it is important to develop the new MKI calculation in such a way that it is tailored to each phase to ensure effectivity and efficiency. Also, Mobilis TBI aims to implement this process in projects where MKI use is not asked for in the tender, to demonstrate the sustainability of their projects. Based on this problem description the research objective has been defined as follows:

"Design a process to refine the integration of the MKI calculation and supporting steps into the existing processes for all Mobilis TBI projects. This process must be standardized, auditable and clearly indicate the tasks and responsibilities for all employees involved. This aids in the companies' goals to decrease errors, raise awareness for environmental impacts, and ultimately enhance sustainability efforts within the companies' projects."

This research will investigate the integration of MKI into Mobilis TBI's processes, providing insight on essential components of integrating LCA into existing construction processes. This is crucial for enhancing sustainability measurement in infrastructure projects, raising awareness, and promoting the use of sustainable materials and construction methods.

THEORETICAL BACKGROUND

The objective of this literature review is to explore the topics from existing literature relevant to the current research. In Section 2.1 an in-depth review is conducted regarding the key concepts and definitions associated with the Life Cycle Assessment (LCA). Thereafter, in Section 2.2, particular attention is given to the Milieu Kosten Indicator (MKI), which is the specific LCA of interest for this research. Following this in Section 2.3 a definition of construction phases is given, derived from an examination of the most widely recognized definitions found in the literature. Section 2.4 provides a comprehensive overview of studies that have tried to integrate LCA methodologies into construction processes. These studies form integral components of the research foundation, offering valuable insights into the potentials and challenges linked with this integration. Concluding this literature review, the focus transitions to the literature regarding the strategic implementation of sustainability from a project management perspective. This will be explored through an examination of the Sustainable Project Management Framework, providing insights into effective approaches for introducing and adopting sustainable practices within organizational structures.



2 Theoretical Background

2.1 Life Cycle Assessment

Life Cycle Assessment (LCA) is a method for objectively assessing the environmental impact of processes and products across their entire lifecycle (United States Environmental Protection Agency, 1993). This method is a crucial tool for measuring the sustainability of products and services (Buyle et al., 2013). Using the LCA allows for comparing the environmental impacts of products or services, identifying areas for improvement and facilitating informed decision making (United Nations Environment Programme, 2004). The LCA is internationally standardized under ISO14040 and 14044 and typically has four phases, which are the goal and scope definition, Life Cycle Inventory (LCI), Life Cycle Impact Assessment (LCIA), and interpretation and reporting (ISO, 2006; Khasreen et al., 2009; Ortiz et al., 2009). Firstly, in the goal and scope definition phase the purpose and system boundaries of the LCA are established. Clear definition of the goal and scope is crucial as these can vary significantly. Secondly, in the LCI analysis data is collected on all inputs and outputs within the product system boundary. This data includes for example energy and raw material inputs, products, waste, emissions, and other environmental impacts. Thirdly, data collected in the LCI analysis is used to evaluate environmental impacts in the LCIA phase, which consists of three mandatory steps. Impact categories are selected based on the LCA's goal and scope, with LCI results assigned to these categories for indicator calculation (Buyle et al., 2013). Following this process reveals the environmental impact of the product or process. Finally, in the interpretation and reporting phase, LCIA results are interpreted and reported for decision making. Figure 1 illustrates the LCA framework, showing its iterative application.

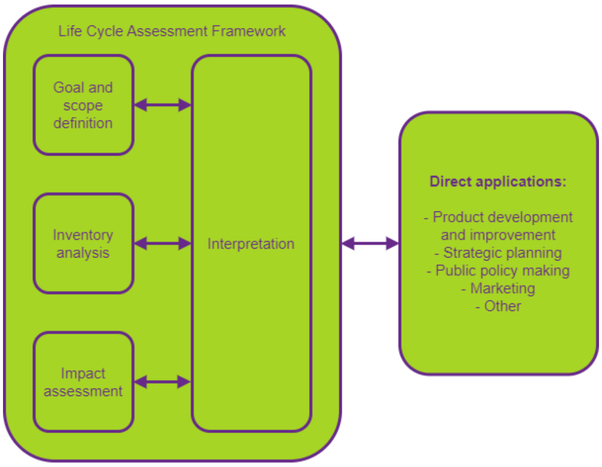


Figure 1 – Life Cycle Assessment framework (ISO, 2006)

While the LCA process is standardized by ISO14040, there is not one manner to conduct an LCA (ISO, 2006; Ortiz et al., 2009). Different LCA methods are utilized, particularly in the initial phases of the goal and scope definition and LCIA differences can be seen. In the goal and scope phase, it is crucial to clearly define the goal and system boundaries. Four main inputs are influencing the results of the LCA, the temporary systems boundary, spatial system boundary, functional unit and the project lifespan (Abd Rashid & Yusoff, 2015). The temporal system boundary sets study limits, determining which inputs and outputs are included in the LCA. System boundaries vary, including cradle-to-grave or cradle-to-gate approaches. The system boundary should be chosen in way that best represents the product or process lifecycle (Zampori et al., 2016). Figure 2 displays the life cycle phases. The spatial system boundary sets the geographical scope of the LCA, ensuring data representativeness for the product or process area. The functional unit defines the function of the product or process and serves as a reference unit relating inputs and outputs. Defining a functional unit is crucial for meaningful environmental impact comparison of products or processes. In construction, the project lifespan significantly influences its environmental footprint over time. Various tools and databases are available for the LCIA, assessing environmental impacts of products or processes (Dos Santos et al., 2017; Hillege, 2022; Martínez-Rocamora et al., 2016; Ortiz et al., 2009). Each tool has its own approach, impacting categories, and data requirements. Method selection for an LCA depends on assessment goals, scope, and available data (ISO, 2006). The choice of method depends on the product or process type, with no method being superior (Dos Santos et al., 2017; ISO, 2006).

Product / Manufacture stage [A1-A3]			Construction Process Stage [A4-A5]		Use [B1-B7]							End-of-Life Stage [C1-C4]				Benefits & Loads Beyond [D]
					Building Fabric					Operation of the Building						
Raw Material Extract / Process / Supply	Transport	Manufacture	Transport to the Site	Assembly / Install in the Building	Use / Application of Installed Products	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	Deconstruction / Demolition	Transport to Waste Process	Reuse-Recovery-Recycle	Disposal	Reuse - Recovery - Recycle Potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Cradle-to-Gate			Gate-to-Grave													
Cradle-to-Grave																
Cradle-to-Cradle																

Figure 2 – LCA Phases (Köseci, 2018)

2.2 DuboCalc & MKI

The relevant LCA tool for this research is DuboCalc, which integrates with the Nationale Milieu Database (NMD). The interest for this tool is driven by the mandate for its use in infrastructure projects in the Netherlands (Nationale Milieu Database, 2020). DuboCalc, developed by Rijkswaterstaat for the Dutch construction sector, promotes sustainability in procurement and is currently mandatory for large tenders (DuboCalc, 2023). The DuboCalc tool is an LCIA tool, leaving significant variability in the goal and scope definition phase, determined by the project's client. DuboCalc computes the MKI, a metric for environmental impact assessment. It assigns a monetary value to environmental impact, incorporating social costs. A sustainable project has low social costs, and, thus, a low MKI value. This method condenses all environmental impacts into a single value. Originally 11 environmental impact indicators were included in the MKI. However, in 2020 the determination method of the MKI was changed and the number of indicators increased from 11 to 19 (Nationale Milieu Database, 2023). This change was based on the newest European norm and currently the materials are redetermined to fit the new determination method. The MKI is computed by multiplying environmental impacts from LCA by financial values, summing across all indicators. An example calculation with 11 indicators is shown in Table 1. The new determination method is not in use yet as the transition process is ongoing (Nationale Milieu Database, 2023).

Table 1 – Example MKI calculation for a 1m3 concrete (Pianoo, 2020; Vosmaer, 2021)

Environment effect category	Equivalent unit	Quantity (eq.)	Weighing factor (€/kg)	Result
Exhaustion of abiotic raw materials (excluding fossil energy carriers)	**SB eq.**	**1.14E-04**	**€ 0,16**	**€ 0,00**
Exhaustion of fossil energy carriers	**Sb eq.**	**3.39E-01**	**€ 0,16**	**€ 0,05**
Global Warming Potential 100 years	**CO_2 eq.**	**1.17E+02**	**€ 0,05**	**€ 5,83**
Ozone Depletion	**CFK-11 eq.**	**5.82E-06**	**€ 30,00**	**€ 0,00**
Photochemical oxidant formation	**C_2H_4 eq.**	**4.56E-02**	**€ 2,00**	**€ 0,09**
Eutrophication	**SO_2 eq.**	**5.30E-01**	**€ 4,00**	**€ 2,12**
Acidification	**PO4 eq.**	**8.62E-02**	**€ 9,00**	**€ 0,78**
Human toxicity	**1,4-DCB eq.**	**1.80E+01**	**€ 0,09**	**€ 1,62**
Freshwater aquatic toxicity	**1,4-DCB eq.**	**4.81E-01**	**€ 0,03**	**€ 0,01**
Marine aquatic toxicity	**1,4-DCB eq.**	**2.81E+02**	**€ 0,0001**	**€ 0,28**
Terrestrial toxicity	**1,4-DCB eq.**	**1.88E-01**	**€ 0,06**	**€ 0,01**
	Result of sum all 11 effect categories:			**€10,80/m^3**

By integrating an objective sustainability metric such as MKI into procurement, infrastructure project sustainability can improve. Unlike traditional procurement, tenders incorporating MKI consider environmental impact alongside price and quality, ensuring sustainability in the process. This method promotes sustainable development by challenging contractors to select products and elements with lower MKI values, indicating fewer social costs involved in addressing the environmental impact. Prioritizing sustainability in procurement equips the project to reduce its environmental footprint. Dutch governmental agencies, have a specific tendering process for new project, in which they set the MKI range based on an initial design estimate. Bids must meet the upper MKI value limit to be considered valid. However, contractors can earn fictional discounts on their bids when having an MKI value lower than the upper limit. There is a linear relationship between the MKI value and the fictional deduction, the maximum deduction being achieved at the lower limit.

The fictional deduction system encourages innovation for more cost-effective and eco-friendly contractor solutions. When comparing standard and innovative designs, the latter may have slightly higher costs. Using the fictional deduction system, contractors can reduce bidding prices, making the innovative solution financially appealing (Pianoo, 2020). Furthermore, this approach promotes sustainable practices throughout the construction chain ensuring transparency. By incorporating DuboCalc, sustainability is prioritized from the start by reduction material waste during transportation or reusing materials. This is reflected in the MKI, which makes losses and emissions visible throughout the chain. As a result, suppliers are motivated to adopt sustainable practices to achieve lower contract MKI scores and secure bids. The MKI system also encourages innovation and improvement of products and services, which can be included in the NMD environmental database. Figure 3 illustrates the broader sustainability advantages of this approach.

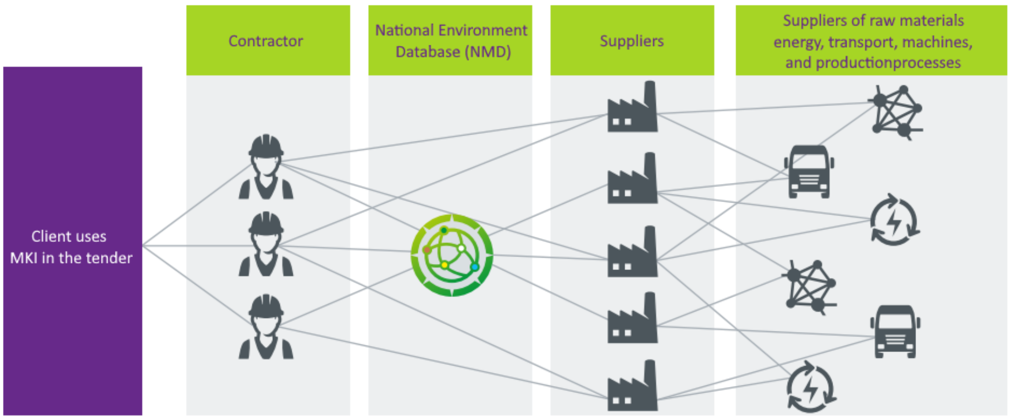


Figure 3 – MKI stimulates improvement in the supply chain (Pianoo, 2020)

2.3 Construction Processes

To integrate the MKI calculation into projects, it is crucial to understand and define construction processes and phases. This Section explores various definitions, weighing pros and cons. Defining construction phases is crucial for several reasons. It ensures contextual relevance, forming the foundation for seamless integration with existing practices. This alignment is vital for effective integration of research findings into ongoing operations, leading to more successful outcomes. Furthermore, well-defined construction phases offer transparency in the research methodology.

Various project management methods and frameworks are available, each with unique approaches to project management. Notable definitions of construction phases are the PMBOK, PRINCE2, and EPC phases. PMBOK, which stands for Project Management Body of Knowledge, defines phases like initiation, planning, execution, monitoring and controlling, and closing, offering a comprehensive approach to project management (Project Management Institute, 2023; Ruiz-Martin & Poza, 2015).

PRINCE2, or Projects in Controlled Environments, is a structured and process-based methodology with phases including starting up a project, initiating, directing, controlling a stage, managing product delivery, managing a stage boundary, and closing a project (Lianying et al., 2012; Matos & Lopes, 2013). Finally, the EPC phases, Engineering, Procurement, and Construction, are widely used in literature but are not entirely applicable to the existing processes seen in this research (Habibi et al., 2019). Considering the research's objective of enhancing sustainability in construction projects, a methodology that provides flexibility and clear project planning is most suitable. PMBOK, with its flexibility and alignment with project phases seen in this research, emerges as a strong candidate.

Two additional points regarding construction processes should be considered for this research. Firstly, change during construction is inevitable. Yet, initiating change earlier, such as in the design phase, increases potential value and reduces costs (Burke, 1990). Figure 4 illustrates the interaction between construction phase, cost of change, and potential value addition. This interaction is crucial for this research, as enhancing MKI for projects is best achieved when the newly designed process shows improvement, particularly in the design phase. Secondly, within construction processes, various groups, and employees with different functions work on the project. They are interconnected through produced outputs, and their activities are typically overlapping, rather than discrete or one-time events, visualized in Figure 5. This is significant for the research as task responsibilities need defining, which may change throughout the project but not at discrete moments.

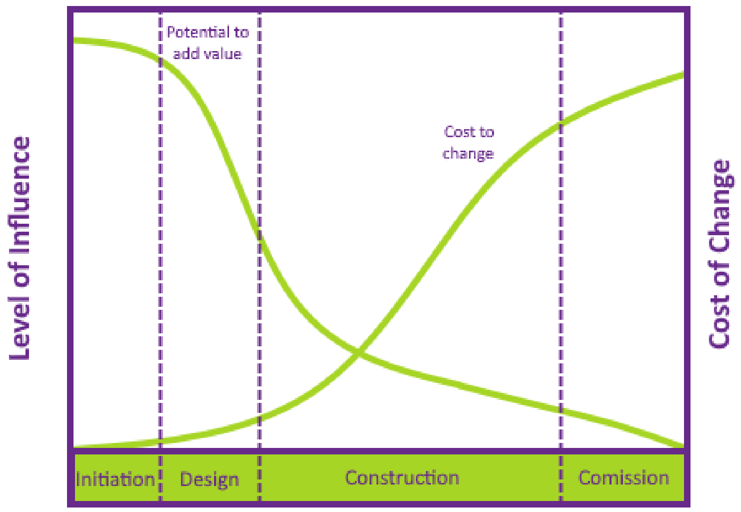


Figure 4 – Interaction between the construction phases and level of influence and cost of change (Burke, 1990)

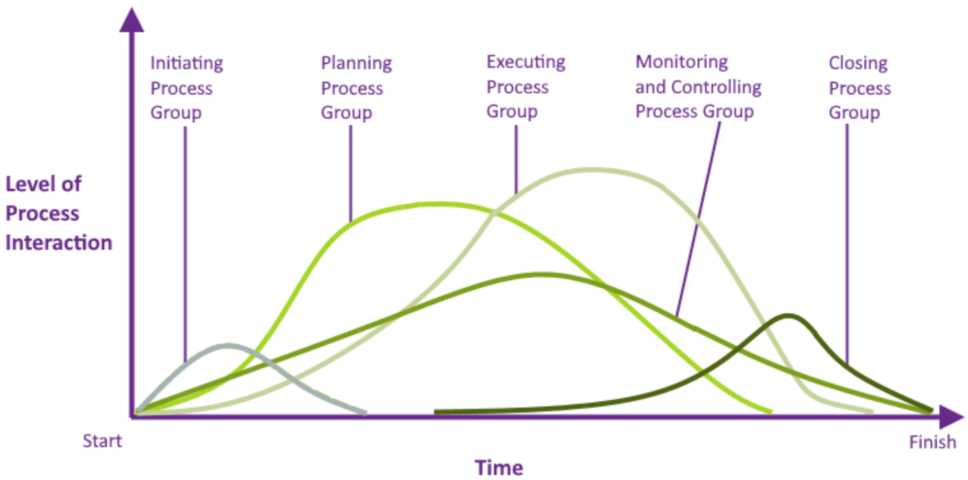


Figure 5 – Overlap of project groups during construction projects (Project Management Institute, 2013)

2.4 Implementation of LCA Tools in Construction Processes

Sections 2.1 and 2.3 introduced terminology relevant to LCA, MKI, and constructions processes. This Section discusses the current literature on LCA tools in construction processes for each of the construction phases. In the Initiating phase, Scherz et al. (2022) conducted a systematic review on LCA usage in public building procurement. Their findings show that while sustainable tendering is discussed, LCA methods are rarely used, leaving a knowledge gap in integrating LCA in this phase for infrastructure projects (Patel & Ruparathna, 2021).

For the planning phase, extensive recent research covers implementing LCA Tools (Cavalliere et al., 2019; Soust-Verdaguer et al., 2017). Especially the implementation of LCA tools using BIM, a digital tool for creating 3D models of buildings or infrastructure, including information on building materials and components. Llatas et al. (2020) demonstrated the integration of LCA into the planning phase through BIM. Designers could effortlessly assess the environmental impact of different design choices using an automated and standardized approach. However, implementing LCA tools in BIM poses challenges. Naneva et al. (2020) discovered research focused either on early conceptual phases with simplified LCA methods yielding inaccurate outcomes or on late detailed design phases, too late for design alterations. An example is Jrade and Jalei (2014) who presented a methodology integrating BIM and LCA tools using a database for designing sustainable building projects, featuring a 3D BIM module, LCA module, LEED, and cost module. However, limitations include inapplicability to the detailed design stage and incomplete coverage of sustainable elements. To address the issue of the phase-specific studies, Naneva et al. (2020) proposed a process structured LCA database using information from databases containing only traditional components and materials. This method allowed for continuous LCA calculation throughout the design phase using the BIM tool. This method is useful for mass construction, but not for innovative solutions. Developing databases for bio-based, recycled, and innovative materials, would simplify their integration. A similar result was presented by the study by Santos et al. (2019) who suggested that integrating LCA analysis into BIM environments, required more information than typically found in BIM Models. They further noted the lack of sustainable properties to store values for environmental impact categories.

Although there is extensive literature on implementing LCA tools in construction processes with BIM, research on implementing LCA without BIM is scarce. This is significant to this research as the use of BIM for LCA implementation has limitations for integrating the MKI. The MKI must be calculated in DuboCalc, which makes automation of the process currently impossible and therefore labor intensive. Furthermore, there is an absence of a comprehensive database for all required materials and the inability to cover all environmental impact categories also limits the use of BIM. Furthermore, no literature addresses LCA control in the realization, monitoring, and closing phases, limiting applicability across all construction phases. This literature review highlights a gap in identifying key concepts for LCA implementation in construction phases. Further research could help integrate LCA and MKI into construction processes.

2.5 Sustainable Project Management Framework

This study shifts focus from the technical aspects of LCA implementation using BIM to emphasize on organizational and project management dimensions. This Section is directed towards current literature examining organizations using Sustainable Project Management and an elaboration of the Sustainable Project Management (SPM) Framework created by Armenia et al. (2019).

Traditional project management often overlooks sustainability despite its growing importance, leading to propose diverse approaches (de la Cruz López et al., 2021). Authors criticized that sustainability is an addition to management functions, advocating instead for a central role in project management (Kivilä et al., 2017). After a call to address sustainability fragmentation in project management, the topic gained substantial attention. A search from 2018 to 2021 reveals around 300 papers on 'project management sustainability. However, the interpretation of the term varies and it seems that sustainability transcends individual-organizational dynamics (Donald, 2023). Finding multiple papers on topic is challenging as studies often reference each other for information instead of utilizing them to enhance theories or frameworks. Furthermore, many researchers explored sustainability and project management separately, there is limited effort in developing modern approaches for implementing sustainable project management practices (Chawla et al., 2018).

The need for a sustainability project management framework grows (Berényi & Soltész, 2022; Chawla et al., 2018; Donald, 2023; Ebekozien et al., 2023). Chawla et al. (2018) emphasize that prioritizing sustainability is vital for long-term profitability amidst ongoing uncertainties and resource depletion. Therefore, businesses must address sustainability across all aspects of their operations. Armenia et al. (2019) noted a gap in sustainability within project management methodologies such as PMBOK, prompting further investigation. They emphasized the link between project management and sustainability, highlighting the necessity for exploration. The authors conducted a systematic literature review on integrating sustainability and project management. The literature review conducted in their research gathered papers on various dimensions of SPM, identifying five critical dimensions: Corporate Policies and Practices, Resource Management, Life Cycle Orientation, Stakeholder Engagement, and Organizational Learning. These dimensions form the framework for implementing sustainability principles in SPM and can be seen in Figure 6.

Firstly, 'Corporate Policies and Practices' include rules, processes, and decisions aligning organizational strategy with projects. Sustainability principles could be integrated using sustainability driven projects or the assessment of key indicators. Crucially, sustainability implementation begins at the corporate level, laying the foundation for SPM. Secondly, 'Resource Management' in SPM extends beyond asset allocation and budgeting, encompassing the relationship between project stakeholders and utilized resources. Sustainability aims to minimize resource use across a project's lifecycle, including natural, financial, and human resources. Thirdly, for the 'Extended project life cycle' of projects, diverse approaches exist without a clear consensus on the most suitable one. SPM urges organizations to expand their focus beyond the traditional project life cycle to consider the entire life cycle of project-related assets, making informed decision-making possible. Fourthly, 'Stakeholder Engagement' is also crucial in SPM. Effective stakeholder management is fundamental for project success, especially in sustainability contexts. Understanding and responding to diverse stakeholder perspectives is essential for sustainability. Categorizing stakeholders into macro blocks such as individuals, organizations, and global society helps manage these complex relationships. Finally, 'Organizational Learning' is deeply intertwined with successful project management, offering continuous learning opportunities through knowledge management processes. Learning prevents mistakes and inefficiencies, improving project outcomes. Moreover, organizations should invest in sustainability training and education for project teams, fostering higher engagement and performance aligned with sustainable practices and objectives.

Understanding how the five dimensions of the SPM framework interact and influence each other is crucial. Arrows between dimensions symbolize these dynamic relationships. For example, In the connection between 'Organizational Learning' and 'Corporate Policies & Practices', an organization learns from its projects, adapting and refining corporate policies and practices to better align with sustainability principles. Conversely, established corporate policies and practices influence the learning processes within the organization, shaping how sustainability is integrated into project management. Another example is the connection between 'Resource Management' and 'Stakeholder

Engagement'. Resource management decisions, including human resource allocation, impact how stakeholders are engaged. Conversely, stakeholder engagement processes provide valuable input for optimizing resource management practices, ensuring alignment with stakeholder expectations. These connections underscore the interconnectedness and interdependence of dimensions within SPM, illustrating how actions and decisions in one dimension can have implications and feedback effects on others. By incorporating the five dimensions and their interconnectedness, the framework enables project-based organizations to assess and adjust their operations.

The theoretical framework proposed by Armenia et al. (2019) brings several advantages to the table when it comes to integrating MKI into existing construction processes. To begin with, this method draws its foundations from PMBOK, a widely acknowledged and respected source for understanding project management. Moreover, the framework's relevance is strengthened by its applicability to this research, with an emphasis on sustainability and its connection to project management. The framework incorporates factors crucial to sustainable project management, including stakeholder focus. Success hinges on stakeholders and employees, essential elements integrated into this specific framework (Blais & Agbodoh-Falschau, 2023; Donald, 2023). Furthermore, Armenia et al. (2019) provide a structured approach to integrating sustainability into project management, addressing key challenges. Other frameworks emphasize improving construction project performance and sustainability through practical project management methodologies (Ebekozien et al., 2023). Similarly, Fang et al. (2022) acknowledges project management as an enabling discipline for actualizing projects and emphasizes the importance of integrating knowledge, methods, and skills to govern projects effectively. Armenia et al. (2019) adopted an interdisciplinary approach, combining project management, sustainability, and organizational behavior concepts for a holistic understanding of sustainable project management. Moreover, Dafevwakpo et al. (2023) highlight the trend towards integrating project management and sustainable development, underscoring the importance of interdisciplinary collaboration in addressing sustainability challenges. The structured nature of the framework offers a systematic approach for organizing the data (Arabpour & Silvius, 2023). This structured framework provides the basis for a well-organized and coherent analysis, facilitating the development of an effective integration process. The elaborated theoretical framework encompasses a broad spectrum of considerations within its dimensions (Blak Bernat et al., 2023). This inclusivity ensures comprehensive coverage and adaptability to the unique needs and context of the research.

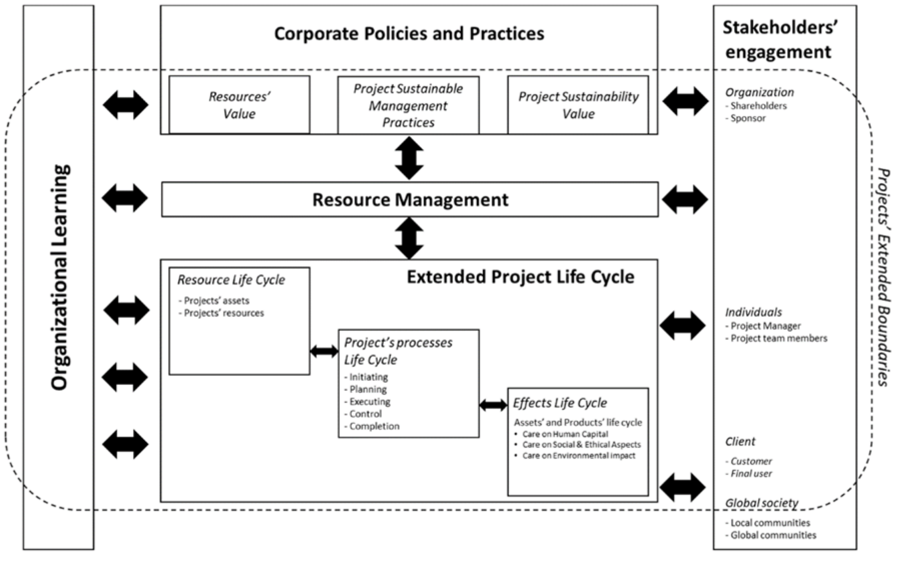
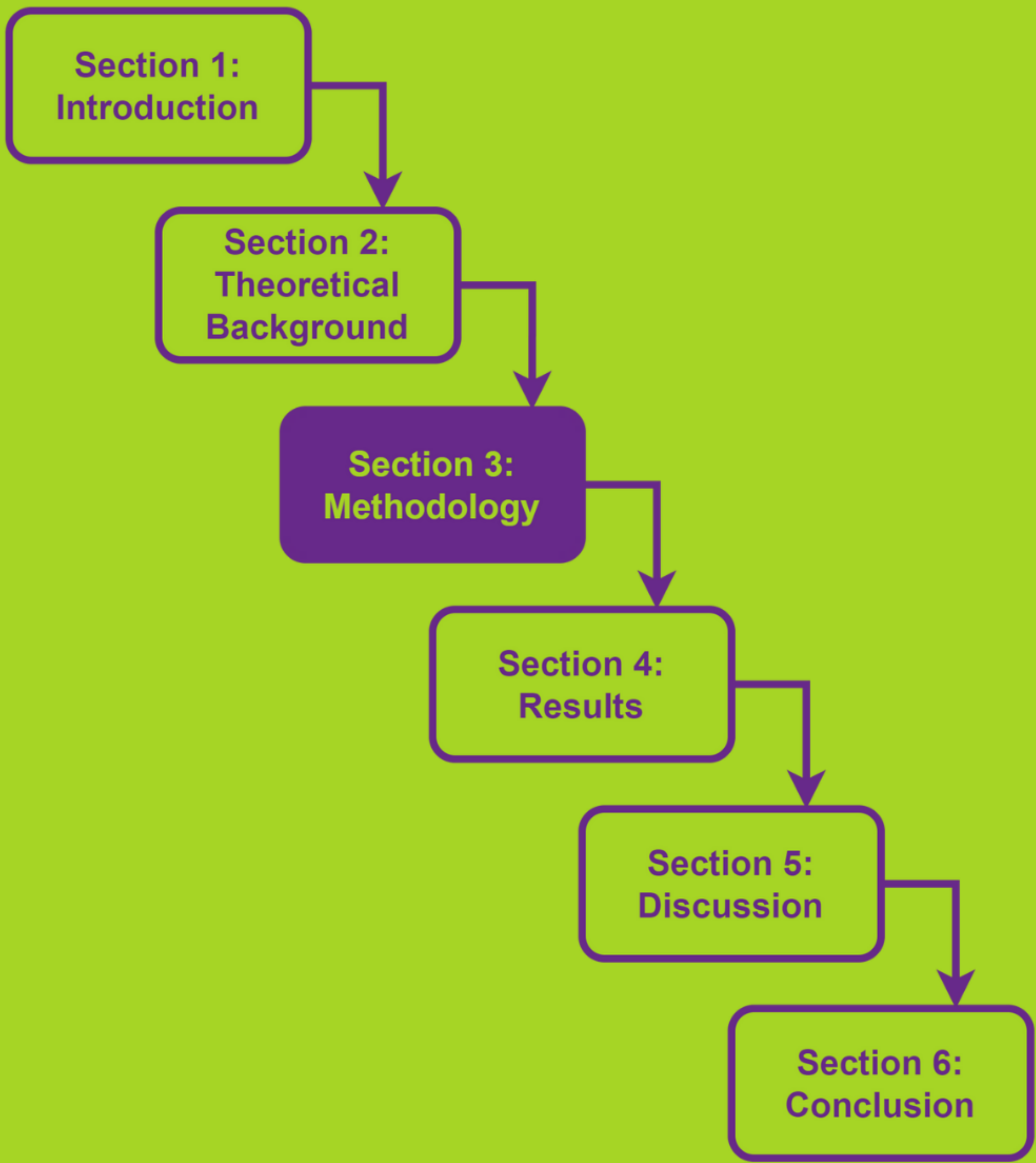


Figure 6 – Sustainable Project Management Theoretical Framework (Armenia et al., 2019)

This Section introduces the applied research methodology in the form of Design Science Research Methodology (DSRM). A detailed exploration of DSRM explains its principles and the relevance of this methodology for this particular research. Thereafter, Section 3.2 elaborates on this research's design problem, main research question and the six sub-questions. Finally, in Section 3.3 all of the used methodologies are explained for each of the six activities conducted in the DSRM for this research. The methodologies intricacies are elaborated for all relevant aspects of the methodology.

METHODOLOGY



3 Research Methodology

3.1 Design Science Research

In formulating the MKI process for Mobilis TBI, it is important to employ a research methodology which not only facilitates the creation of new scientific knowledge but also aligns with the defined objectives. Design Science Research (DSR) emerged as a fitting approach, particularly recognized for its effectiveness in Information Systems, Operations Management, and Organization Development (Dresch et al., 2019; Hevner et al., 2004; van Aken, 2007; Wieringa, 2014). According to March & Smith (1995), DSR is characterized by the creation and evaluation of artifacts aimed at solving identified organizational challenges. This involves a meticulous process consisting of the design of artifacts to address the observed problems, making research contributions, evaluating the design, and effectively communicating research outcomes to the appropriate audiences. The artifacts, representing the solutions to field problems, produced through DSR, are acknowledged for their thorough testing and well-documented innovative designs (van Aken et al., 2016).

Hevner et al. (2004) were the first to identify the purpose of DSR in information systems field problems. Their paper provided guidelines and evaluation methods to structure the process of DSR for information systems research. Van Aken et al. (2007) proposed a design science approach that offered new perspectives on how interventions using DSR can support effective organizational change. They noted that evaluating organizational designs is not an easy task. In many situations, evaluation methods for engineering designs, such as mathematical methods, are not applicable for organizational designs. Nevertheless, other evaluation methods, such as case based reasoning, can be used in DSR as elaborated upon by Van Aken et al. (2007).

Peffers et al. (2007) identified a notable gap in the field of DSR, recognizing the absence of a universally accepted methodology to guide researchers and a standardized template for presenting the findings. In response to this, they introduced the Design Science Research Methodology (DSRM), a comprehensive framework that incorporates essential principles, practices, and procedures necessary for conducting DS research. The DSRM was created using three key objectives: alignment with the existing literature, creating a structured process model for executing DSR, and offering a conceptual framework for the presentation and evaluation of DSR. The DSRM Framework can be seen in Figure 7.

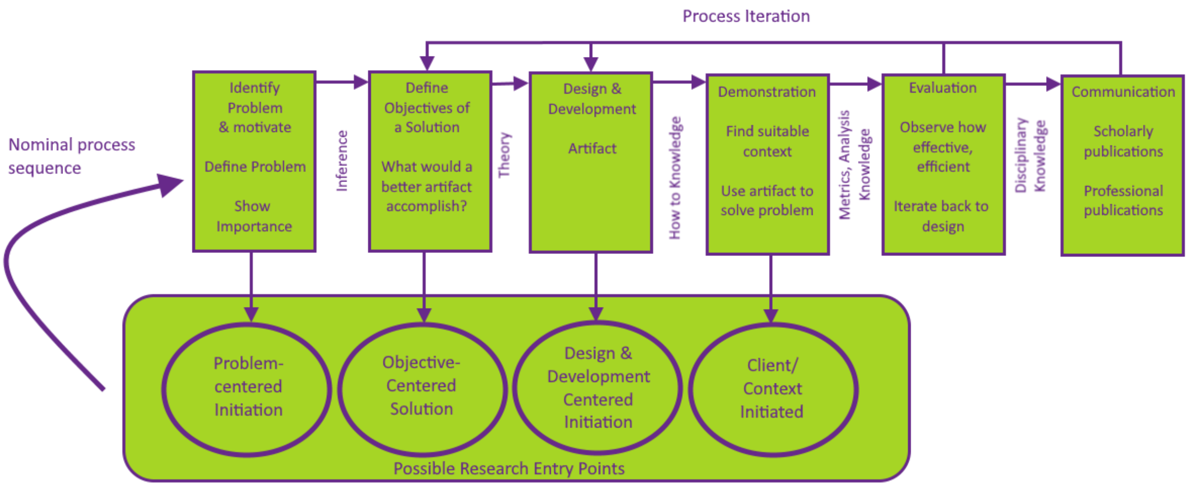


Figure 7 – Design Science Research Methodology (Peffers et al., 2007)

The DSRM consists of six distinct activities that are strategically organized in a nominally sequential order, providing a systematic guide for researchers engaging in DSR. The DSRM unfolds through the following activities: problem identification and motivation, definition of objectives for a solution, design and development, demonstration, evaluation, and communication.

The rationale behind adopting the DSRM lies in its effectiveness in tackling organizational challenges through the design and development of artifacts, while contributing to research advancements. The model by Peffers et al. (2007) serves as a widely accepted framework for several reasons. Firstly, it maintains consistency with the existing body of literature, ensuring alignment with established principles and knowledge. Secondly, it furnishes a structured and logical sequence for researchers to follow, thereby enhancing the clarity and coherence of the research process. This makes the DSRM a valuable tool by providing a robust methodology that encompasses problem-solving, research innovation, and methodical communication of findings.

3.2 Research Questions

In the previous Section the DSRM by Peffers et al. (2007) has been elaborated. This method involves two main parts, namely the design of the artifact and the creation of knowledge (Wieringa, 2014). These parts correspond with two different research problems, namely, design problems and knowledge questions. Design problems require a change in the actual situation and are solved by a solution which is evaluated based on stakeholder goals. Research questions on the other hand do not require change of the situation but ask for knowledge about the specific situation. These questions do not depend on the goals of the stakeholder. Within this Section the design problem and knowledge question for this research are elaborated.

3.2.1 Design Problem

This DSR aims to address the field problem faced by Mobilis TBI. As elaborated upon in Section 1, Mobilis TBI has not effectively integrated the MKI calculations and the supporting activities into their existing processes during the initiating, planning, and realization phases. The use of MKI calculations as an award criterion during tenders for infrastructure projects in the Netherlands is becoming increasingly common, particularly for clients such as Rijkswaterstaat, ProRail and the Provinces who are the client for many of Mobilis TBI's projects. This research aims to find a solution to this problem by effectively integrating the MKI calculations into a new standardized process at Mobilis TBI, which can be used for all projects. This gives the following design problem:

Refine the integration of the MKI calculations and supporting activities in the currently existing processes for projects of Mobilis TBI by designing a new process for calculating the MKI which satisfies the aim to be standardized, auditable, and clear.

3.2.2 Knowledge Questions

To design the new process which integrates the MKI calculations required by Mobilis TBI, specific knowledge must be gathered using knowledge questions. These questions are answered during each of the stages of the DSR process. Depending on the question the questions are answered using three types of data, which are scientific literature, documentation from cases studies from Mobilis TBI, and expert interviews. Which data collection method will be used for which question is elaborated in Section 3.3. The main knowledge question can be seen below:

What are the essential considerations of incorporating the MKI calculation into existing construction processes in infrastructure construction projects for the initiation, planning, and realization phases?

This main question will be accompanied with sub-questions that will help answer the main question. These sub-questions correspond with the activities of the DSRM and can be seen below:

1. What are the main considerations and problems in establishing a standardized process for calculating the MKI in infrastructure projects? (Problem Identification)
2. What are the objectives for designing a standardized process for MKI calculation in infrastructure projects, considering the identified problems? (Objective Definition)
3. What are the necessary design features integrated in the new MKI process for infrastructure projects, derived from the defined design principles (Design & Development)
4. What modifications, refinements and adjustments are necessary based on the demonstration of the developed MKI process? (Demonstration)
5. To what extent have the identified problems been effectively addressed and resolved through the creation of the newly developed artifact? (Evaluation)
6. How can the research findings be communicated effectively to relevant audiences for further academic research and to optimize and guide the implementation of the newly developed process? (Communication)

3.3 Research Method

This research aims to address Mobilis TBI's design problem using DSRM, as outlined in Section 3.1 by Peffers et al. (2007). It follows all six activities detailed in Section 3.1, with methods for each activity explained in the subsequent subsections.

3.3.1 Problem Identification

The first activity of DSRM, 'Problem Identification', involves defining the research problem, breaking it down for a comprehensive solution, and justifying the value (Peffers et al., 2007). First, the research addresses the first sub-question by identifying key aspects and main challenges in developing standardized process for calculating MKI for infrastructure projects. Mobilis TBI's original MKI calculation methods and supporting practices have been examined by drawing insights from three separate data sources.

Firstly, relevant studies were sought in academic literature aligning with the research objectives. Papers addressing key components of the new process design and aligned with the research goals were selected for further analysis. The snowballing method was used to make sure the literature was thoroughly reviewed (Wohlin, 2014). This approach continued until data triangulation indicated that further literature review would not yield new relevant data. Secondly, project documentation was examined to understand the current application of the MKI method. Mobilis TBI provided relevant documents from four projects, including MKI estimates, progress reports, management plans, and environmental impact reduction plans. These documents provided insights on practical implementation of the MKI process, offering insights on how the MKI is calculated in projects. Data triangulation ensured that documentation was appropriate for the diagnosis phase and offers a complete picture of the current process. Thirdly, expert interviews were conducted to obtain firsthand knowledge of the existing MKI process. Mobilis TBI employees directly or potentially involved in the current or future MKI process were interviewed. The aim was to involve individuals with practical project experience involving the MKI. 13 participants were selected, and all invited employees accepted the invite. Two more participants were identified during the interview process, totaling 15 participants. A list of interviews can be found in Table 2. The interview guide was semi-structured, allowing participants to steer the interview and prioritize aspects they deem crucial for the development of the new MKI artifact(Adams, 2015). The complete interview guide can be seen in Appendix A. Furthermore, participants granted permission to record and transcribe the interviews, aiding systematic data analysis (Widodo, 2014).

Table 2 – Participant list of the interviews in the diagnosis phase.

Interview	Function	Experience	Construction phases
1	Environmental Coördinator	Multiple Projects	All phases
2	Specialist/Advisor	Sluis Eefde and Rijnlandroute	All phases
3	Lead Designer	Sluis Eefde en Onderdoorgang Vierpaardjes Venlo	Tender and Design phase
4	Tendermanager	Multiple ProRail Tenders	Tender phase
5	Tendermanager	A27-Noord and Maanschoten	Tender phase
6	Teammanager BIM and Modelling	Maanschoten and Rijnlandroute	Tender and Design phase
7	Teammanager Constructors	Rijnlandroute, Onderdoorgang Nunspeet and Onderdoorgang Vierpaardjes Venlo	Tender and Design phase
8	Project Control	Singelgrachtgarage Marnix	Design and Realization phase
9	Planning Engineer	Singelgrachtgarage Marnix	Design and Realization phase
10	Project Manager	Singelgrachtgarage Marnix	Design and Realization phase
11	Contract Manager	Rijnlandroute and Onderdoorgang Vierpaardjes Venlo	All phases
12	Project Manager / Project Control	Rijnlandroute and A27-Noord	Design and Realization phase
13	Contract Manager	Multiple projects	All phases
14	Purchaser	Onderdoorgang Vierpaardjes Venlo	Design and Realization phase
15	Calculator	Onderdoorgang Vierpaardjes Venlo	Tender phase

During the analysis phase, these interviews have been treated as unstructured interviews. Data from three sources were systematically analyzed using inductive line-by-line coding, categorizing and labeling each code (Vears & Gillam, 2022). Subsequently, the data was aligned with the SPM framework detailed in Section 2.5. This approach aligned issues with existing literature, enabling an understanding of their nature and characteristics. Integrating them into the SPM framework provided insights in the underlying dynamics. Data from these sources was coded using ATLAS.ti, which is a specialized software for qualitative analysis (Friese, 2019). This tool allowed for a thorough examination of the data, revealing hidden themes and patterns. Triangulation identified consistent patterns in the raw data, crucial for ensuring analysis reliability and validity by confirming process aspects across multiple data sources (Carter et al., 2014). This understanding formed the foundation for the next research activity.

During the next step of 'Problem Identification' activity, a focus group was conducted to validate findings and expand insights, engaging experts to ensure focus on critical problems and combine diverse expertise for a comprehensive view (Gundumogula, 2020; Tümen Akyldiz & Ahmed, 2021). An expert team of five employees, with diverse functions and expertise, was assembled for the focus groups, which can be seen in Table 3. The inclusion of different expertise enriched the process. The first focus group discussion, detailed in Appendix B followed a semi-structured format to ensure effectiveness. Experts were provided with brief summaries of each identified problem during the diagnosis phase and then were asked to discuss its relevance and accuracy. The session was audio recorded to ensure comprehensive documentation, and a summary was distributed to participants for their review, enabling agreement with the results and any necessary additions or changes.

Table 3 – Assembled experts for the focus groups

Name	Function	Expertise
Marjan Kloos	Environmental Coördinator	Environment
Bernice Hofland	Project Management Coordinator	Processes
Arjan Verweij	Head of Department Design and Planning	Management
Oscar Ouwerkerk	Design Leader	Design
Ron van der Zwet	Planning Engineer	Realization

3.3.2 Objective Definition

Activity two, ‘Objective Definition’, involves establishing the objectives for a solution based on the defined problem and an understanding of what is feasible. Objectives may be quantitative, indicating improvements over existing solutions, or qualitative, outlining how a new artifact will address previously unexplored problems. These objectives should be logically derived from the problem specification, requiring knowledge of the current state of problems, existing solutions, and their effectiveness (Peffers et al., 2007). This research executed this step by translating the identified problems to design principles. Design principles are considered to be the prescriptive knowledge of DSR projects and were used to guide the design of the final artefact (Chandra et al., 2015). Therefore, these design principles were fundamental for making design choices and select design features which would become the foundation for developing the new MKI process. The design were formulated according to the structure of Chandra et al. (2015). This structure consists of a property, activity, and boundary conditions. The template of the design principles in this research is as follows:

Enable with a standardized process for the creation of [property – In terms of form and function], so that project teams [activity – in terms of action], considering [boundary conditions – user group’s characteristics or implementation settings].

Following the development of these design principles, a second focus group was conducted. The primary objective of this focus group was to specify and finalize the newly created design principles and prioritize them based on their significance for the MKI process's development. To achieve this, the MoSCoW method was employed, which stands for Must-haves, Should-haves, Could-haves, and Won't-haves (Kravchenko et al., 2022). This method enabled participants to categorize design requirements according to their importance and relevance while ensuring that the resulting MKI process is aligned with key priorities and tailored to meet the core objectives while being feasible to implement in the solution. The guide for the second focus group can be seen in Appendix C.

3.3.3 Design & Development

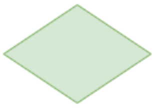
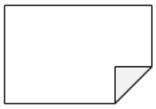
Activity three, ‘Design & Development’, involves the design and development of the research artifact. This activity includes defining the artifacts functionality and architecture, followed by its creation (Peffers et al., 2007). The design principles set guidelines for the new processes’ desired outcomes and characteristics, which were then translated into concrete design features. (Chanson et al., 2019; Schoormann et al., 2022). Insights from interviews and focus groups shaped the design to align with real-world requirements and end-user expectations. Each design principle was carefully integrated into the new MKI process features.

The next step was creating the new MKI process. To do this, a method had to be chosen, as processes can be documented in various ways using different applications. Depending on the creator’s knowledge and skills, processes may vary in structure. Without agreed-upon modeling rules, different processes may diverge significantly. So, a methodology understood by all stakeholders is crucial to ensure clarity and application of the process information. Therefore, the MKI process in this research follow the Sensus Methodology, consistent with Mobilis TBI’s approach for all processes (Mobilis & Croonwolter&Dros, 2022).

Sensus, an online application, uses guidelines and modeling rules to ensure uniform process creation (Mobilis & Croonwolter&Dros, 2022). Within Mobilis TBI, Sensus categorizes processes into five layers: Organization', 'Theme', 'Main Process', 'Process', and 'Activity' (Van Doorewaard & Hofland, 2020). In the context of this research, the artifact under consideration is a process. Processes drive effective process management, each with distinct objectives and delivering specific products or services. Process flows illustrate how resources are deployed in sequence to achieve process goals.

The Sensus Method outlines 8 essential process elements: Goal, Customer/Supplier, Input/Output, Framework, Actors/Roles, Resources, Risks/Measures, and SMART. This structured format offers a comprehensive and systematic approach to process management and modeling (Van Doorewaard & Hofland, 2020). When modelling processes, it is crucial to structure them for universal understanding and application by all stakeholders. Maintaining clear and consistent icons is essential for end-users, ensuring ease of comprehension across different processes. Consequently, the Sensus Method employs just eight icon types to maintain consistency. Design conventions, such as icon placement and quantity, must also be followed to prevent inconsistencies (Van Doorewaard & Hofland, 2020). Table 4 displays the icons used in the Sensus method along with their meanings.

Table 4 – Meaning of the Sensus-Method icons (Van Doorewaard & Hofland, 2020)

	Cause / Result		Input Document
	Action		Output Document
	Computer Action		Archive / Register
	Choice		Process Reference

3.3.4 Demonstration

The fourth activity, 'Demonstration,' involves presenting the application of the artifact in addressing specific instances of the identified problem (Peffers et al., 2007). This was carried out in the context of the third focus group, by systematically navigating through the conceptual process step by step. The detailed guide for this third focus group is available in Appendix D. The objective is to ensure the logical sequence of all process steps in a logical sequence, verify the accuracy of step descriptions, and confirm the inclusion of all necessary tasks within the process. Throughout the demonstration, experts were actively encouraged to intervene when certain steps of the process appeared incomplete or incorrect, allowing for adjustments to be made in the final process. After the focus group, the feedback received from the expert team was integrated into the MKI process. This integration encompassed modifications to the process steps, refinement of team members' roles and responsibilities, and adjustments to the descriptions associated with each process step.

3.3.5 Evaluation

The subsequent phase, 'Evaluation,' is centered on observing and measuring how effectively the artifact contributes to resolving the identified problem. This involves a comparative analysis of the solution objectives outlined in the second activity with the outcomes observed during the demonstration (Peffers et al., 2007). The evaluation was conducted by seeking assessments from experts participating in the third focus group, who were tasked with evaluating the efficiency of the new process in addressing the identified issues. Gonzalez & Sol (2012) conducted a literature review, exploring evaluation techniques and criteria applicable to DSR projects. Their findings suggest that artifacts like the one designed in this research are best assessed using criteria outlined by March & Smith (1995), encompassing Operationality, Efficiency, Generality, and Ease of Use. Operationality refers to the artifact's ability to perform its intended tasks reliably and effectively. Efficiency assesses how well the artifact utilizes resources such as time, money, or personnel to achieve its objectives, while generality assesses the extent to which the artifact can be applied to different contexts or situations. Finally, ease of use is used to evaluate how user friendly the artifact is. An artifact which is easy to use is intuitive, simple to navigate, and accessible to users of varying levels of expertise. In alignment with this insight, the experts in focus group 3 were asked to rate the effectiveness of the new process in tackling each identified problem based on these evaluation criteria, utilizing a Likert scale (Jebb et al., 2021). The detailed guide followed during focus group 3 can be seen in Appendix D.

3.3.6 Communication

During the final activity of this DSRM, the focus is on effectively conveying the significance of the identified problems, sharing the details of the created artifact, emphasizing its utility, novelty, and design rigor to both researchers and relevant audiences. To fulfill the communication requirements of this research, a two-tiered approach has been adopted, involving distinct communication strategies for the research findings and the developed artifact tailored for Mobilis TBI.

In addressing the research findings, this thesis serves as a comprehensive documentation of the outcomes, providing a detailed exploration of the identified problem the intricacies of the artifact, and a critical analysis of its utility and novelty. Concurrently, for the artifact designed for Mobilis TBI, a complementary implementation plan has been created. Within this implementation a strategic roadmap is created for the practical integration of the developed process. The implementation plan outlines how and when this innovative process can be effectively applied, offering a practical guide for stakeholders, and ensuring a seamless transition from theoretical conception to real-world application.

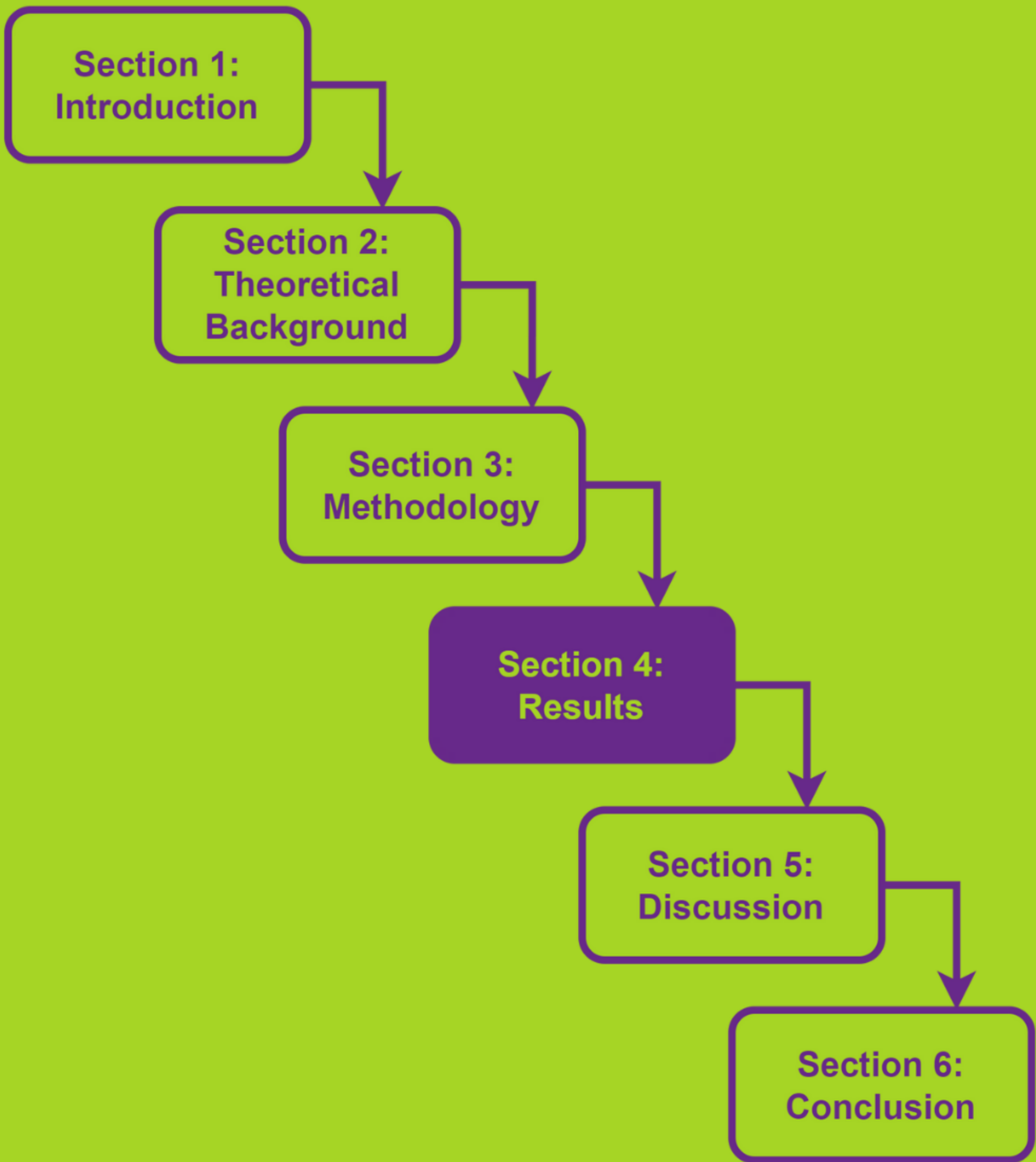
3.3.7 Overview Research Activities

During this research, the Design Science Research Methodology (DSRM), as detailed in Section 3.1, has been used. The systematic application of DSRM ensures a structured and rigorous approach to the investigation, development, and evaluation of the proposed solution. In Table 5, a depiction of all research activities is presented, accompanied by an elaboration of their purpose, and utilized sources.

Table 5 – Summary of conducted research activities

Activity	Description	Sources
Problem Identification	Identification of the current problems in regard to the MKI-process	Literature
		Company documents
		Interviews
		Focus group 1
Objective Definition	Definition of the design principles	Focus group 2
Design & Development	Designing and developing the new MKI-process based on the design principles	Interviews
		Focus group 1
		Focus group 2
Demonstration	Demonstrating the use of the new MKI-process based on the identified problems and design principles	Focus group 3
Evaluation	Evaluating the solutions used to solve the identified problems	Focus group 3
Communication	Communicate the research findings and the artifact of the research	Implementation plan
		Thesis

Section 4 provides an elaboration of the outcomes derived from the various activities undertaken in the course of this research. Each subsection is linked to a specific phase of the Design Science Research Methodology (DSRM), encompassing the entire research process. Section 4.1 delves into the identification of the current problems of the existing MKI-process. Section 4.2 defined the design principles from the identified problems in the objective definition. Section 4.3 elaborates on the design and development of the final artifact, while Section 4.4 elaborates on the demonstration of this final artifact. In Section 4.5 the results of the evaluation of the final artifact is shared and finally Section 4.6 elaborates on the strategies for the communication of the results to the stakeholders.



RESULTS

4 Results

4.1 Problem Identification

This Section elaborates on the findings of the Problem Identification. This activity is essential to gain a thorough understanding of the current situation, identify the key aspects and understand the problems at hand in the existing process. The problems identified during this activity are summarized in this Section based upon the findings of the analysis, including the interviews, documents, and literature. An elaborate presentation of the findings including the precise sources of the findings can be seen in Appendix E and the focus group is summarized in Appendix F. The identified problems are shortly elaborated and methodologically arranged following the theoretical framework discussed in Section 2.5, which can be seen in Figure 6.

Problem 1 - Scope Variability Between Projects

Mobilis TBI projects face a recurring challenge concerning the variability and definition of project scopes. This variability, often shaped by client requisites, underscores the critical need for a meticulous consideration of project boundaries. Since this scope has such big variance from project to project it is not possible to use a standard scope for each project which includes an MKI aspect as could be seen in the document analysis. However, the MKI scope of a project has a big influence on the MKI value, and an unstructured approach to scope definition could introduce disparities and ambiguities in projects. Therefore, it is crucial to acknowledge that while establishing a uniform scope definition is not possible due to variations in client preferences and contractual obligations across projects, efforts should be directed towards achieving a standardized approach to defining the MKI scope. This would ensure clarity regarding the MKI-related aspects for every project and project member, addressing the current lack in this aspect.

In the SPM model this problem is situated at the ‘Corporate Policies & Practices’ dimension as well as the connecting arrow with ‘Resource Management’. Corporate policies and practices play a pivotal role in shaping the definition of projects, particularly their scopes. When these policies lack clarity or structured guidelines regarding scope definition, it results in variations and uncertainties across different projects. This lack of consistency becomes a significant contributor to scope variability. Furthermore, the influence of client requisites on the variability in project scopes underscores a potential issue in how corporate policies guide resource management. Without clear guidelines or structured approaches within these policies related to scope definition, projects may suffer from disparities and ambiguities.

Problem 2 - Unstructured Use of Bandwidth Determination

During the initiation phase of a project, the lower level of project detail results in an increased uncertainty and therefore increased risk concerning the MKI calculation. This uncertainty is caused by several aspects, such as the unavailability of the actual MKI values, uncertainty concerning material availability and unexpected issues which could arise during construction. Due to the higher level of uncertainty, it could be possible that certain parts of the MKI calculation created in the tender of the project cannot be achieved which could cause the possibility of not complying with the EMVI-criteria in the contract. To prevent this, a system is in place where a bandwidth value is defined based on the expected level of risk, which is added to the MKI value to mitigate the risk caused by these uncertainties. However, a significant challenge can be seen during construction projects at Mobilis TBI revolving around the unstructured approach when using the bandwidth during the tender of a project. In many situations it was decided during the tender to reduce the bandwidth, primarily driven by the desire to secure competitive tenders. Despite the potential competitiveness, maintaining a structured bandwidth is recommended to ensure environmental goals are met and financial penalties are avoided.

This problem can be found in the SPM Model at the 'Corporate Policies & Practices' dimension as the unstructured approach to bandwidth determination is rooted in the initiation phase of projects, where initial MKI values are estimated based on the National Material Database (NMD) or historical information. Corporate policies and practices related to project initiation and risk management play a significant role in influencing this unstructured approach.

Problem 3 - Unclear Responsibility and Handover

A significant challenge in Mobilis TBI's large-scale projects involves the allocation of responsibilities and tasks across various tasks of the MKI process. For tasks such as collecting material quantities and calculating the MKI value, responsibilities transition from designers to work preparation, occasionally involving calculator collaboration, as the project advances. The lack of clarity regarding responsibility allocation within each sub-process of the MKI presents a major issue according to the interviewed experts, with employees holding differing views on these responsibilities. While the overall responsibility falls under the tender or project manager overseeing the project, a clear division of responsibilities for each task is crucial. Inconsistencies in responsibility assignment pose a challenge, especially concerning tasks like collecting material quantities and the calculation of the MKI itself.

This problem is located at the 'Corporate Policies & Practices', connecting arrows with 'Organizational Learning' and 'Resource Management', and the 'Projects Processes Life Cycle' of the SPM model. The lack of clarity in responsibility allocation suggests a need for well-defined corporate policies and practices outlining roles within each sub-process of the MKI. Clear guidelines are essential for consistent responsibility assignment as projects progress.

Problem 4 - Lack of Structured Control of Quantities

Another challenge within the MKI process at Mobilis TBI is the absence of a structured approach to control material quantities. This task holds great importance, encompassing two critical components: ensuring the consistency of quantities across different sections of the design, particularly between environmental impact assessments and cost estimations, and verifying that the quantities accurately represent the defined MKI scope of the project. Interviews and the expert discussion have highlighted that discrepancies in quantities of different calculations or inaccuracies concerning the project's scope can lead to errors, affecting both environmental assessments and cost projections. This issue is especially prominent in the latter stages of a tender. During this period quick decisions are required, and several calculations are made simultaneously. It has happened that some of the calculations have not been made using the same material quantities.

This problem can be found in the SPM Model at the 'Corporate Policies & Practices' dimension. The absence of a structured approach to controlling material quantities indicates a potential gap in corporate policies and practices related to the MKI process. When well defined policies are in place to guide the systematic control of material quantities, consistency is ensured across various calculations of the design and representation of the MKI scope.

Problem 5 – Lack of Standard control of MKI during Request of Change

Mobilis TBI currently deals with a challenge related to the absence of a standardized control for managing the implications of a contract change on the MKI value. The issue becomes visible when a change to the contract is initiated, and the implications on the MKI are not consistently addressed and controlled. A notable concern lies in the lack of uniformity in identifying, documenting, and managing MKI across various contractual changes. According to the interviewees this inconsistency increases the probability of errors and misunderstandings, thereby increasing the potential for disruptions in contract execution. The lack of a standardized control mechanism elevates the risk of non-compliance with contractual obligations. Failing to adequately consider MKI implications during contract changes may result in breaches of the contract or financial penalties.

Within the SPM model this problem can be found at the ‘Corporate Policies & Practices’ dimension, as well as the arrow connecting this dimension with the ‘Stakeholder Engagement’ dimension. The standardization of this control during contractual changes must be incorporated in the corporate policies & practices while the communication with the client must also be considered.

Problem 6 - Insufficient Knowledge and Experience with MKI

Mobilis TBI faces a notable challenge related to a lack of knowledge and experience in the MKI calculation process. Adequate knowledge is crucial for informed decision making in various project scenarios and successful implementation. Currently there is an imbalance in distribution of knowledge, with sustainability coordinators possessing most of the expertise regarding sustainability, while technical knowledge and project requirements are concentrated within project teams. To enhance MKI data reporting and calculations, it is vital to share this knowledge due to the collaborative nature of MKI calculations. Furthermore, experience plays a significant role in MKI implementation, allowing employees to make informed decisions in project management. Furthermore, the organization faces a challenge concerning experience as only a limited number of personnel possess experience with multiple MKI projects, hindering the organization’s ability to establish a competitive advantage in MKI-related aspects within projects.

This problem can be found in the SPM Model at ‘Organizational Learning’ and the arrow connecting with ‘Corporate Policies & Practices’. The insufficient knowledge and experience highlight a need for organizational learning. To effectively implement MKI, continuous learning and knowledge-sharing mechanisms could be established to ensure a collective understanding of MKI calculations and foster informed decision-making. Corporate policies could encourage and facilitate knowledge transfer and learning opportunities related to MKI.

Problem 7 - Lack of Awareness Regarding the Existence of an LCA Library

Mobilis TBI faces a challenge stemming from a general unawareness of the existence and functionality of a LCA library within the organization. This library holds critical MKI values associated with different materials, an essential component in the MKI process. Interviews revealed confusion among employees regarding which materials require LCA values and how these values could be gathered. The conducted analysis has pinpointed two primary factors contributing to this challenge: first, the general lack of awareness about the LCA libraries existence and second, the limited comprehension of how to execute an impact analysis to indicate the required LCAs effectively. An additional challenge concerns the potential disclosure of the LCA library as there are concerns regarding data accuracy, given that LCA values become outdated over time as highlighted by the sustainability coordinator of Mobilis TBI.

Within the SPM model this problem can be seen at the ‘Organizational Learning’ and ‘Corporate Policies & Practices’ dimensions and the arrow connecting the two dimensions. The lack of awareness underscores the importance of organizational learning, while corporate policies could encourage awareness and understanding of essential tools such as the LCA library to optimize the MKI process.

Problem 8 - Environmental Goals Mobilis TBI

Another issue at Mobilis TBI revolves around the need to improve clarity regarding the MKI goals for their projects. Through the conducted interviews and the first focus group, it has become clear that sustainability has become a major focus within Mobilis TBI projects. To further increase the focus on delivering more sustainable projects, Mobilis is considering implementing MKI assessments for all their projects, not just those mandated by clients. This will be done with the aim of comparing the environmental impact across their projects and give themselves higher sustainability standards. However, to make this broader approach effective clear internal goals for project teams are necessary. Without defined objectives, this additional work would lead to inefficiencies and wasted time.

This problem can be found in the SPM Model at the 'Project Sustainable Value' dimension. This problem directly relates to the Project Sustainable Value part of the 'Corporate Policies & Practices' dimension as this part describes the value the company gives to sustainably constructing their projects.

PROBLEM 9 - LIMITED CLIENT EMPHASIS ON ENVIRONMENTAL IMPACT IN PROCUREMENT

An important issue in the effectiveness of the MKI process is the level of emphasis placed by clients on environmental considerations during procurement. Nowadays, clients often request MKI calculations to decrease the environmental impact of their projects as elaborated in Section 1 and 2.2. By meeting specific MKI value targets contractors can gain advantages in securing contracts based on the economically most advantageous tender criteria. However, the focus group discussions revealed that despite being essential, the MKI has never decisively influenced design decisions. Price considerations dominate decision-making, favoring cost savings over environmental sustainability. Furthermore, there have been certain instances where the requirements regarding the MKI from the client have been contradictory.

The arrow connecting the 'Stakeholder Engagement' and 'Corporate Policies and Practices' dimensions shows this problems location in the SPM Model. The challenge involves both the need for adjustments in corporate policies and the importance of stakeholder engagement, particularly with clients. The connection highlights that corporate policies should be adjusted to not only internally emphasize environmental goals but also that clients should be engaged to achieve these goals.

PROBLEM 10 - LACK OF PROJECT FOCUSED EMPLOYEES FOR MKI

Another issue identified in the MKI process at Mobilis TBI is the lack of project-focused employees. The core problem revolves around a workforce that does not consistently embrace a project-centric approach regarding the MKI calculations. As a result, the organization faces inefficiencies, missed opportunities, and the potential for suboptimal environmental impact improvements. Since the scope of the MKI varies significantly from one project to another, there is no one-size-fits-all solution or strategy that can be uniformly applied. The complexity of this challenge lies in the fact that addressing it requires a fundamental shift in the mindset and practices of employees across the entire organization. It is not merely about making minor adjustments, but about cultivating a culture of adaptability, responsiveness, and project-centric thinking.

This problem can be found in the SPM Model at 'Organizational Learning' and the connecting arrow to 'Corporate Policies and Practices'. The challenge necessitates a fundamental shift in mindset and practices, emphasizing the importance of organizational learning. Employees need to understand the project-centric approach and adapt to the varying scopes of MKI in different projects. To address the challenge effectively, adjustments in corporate policies and practices are necessary.

PROBLEM 11 - LACK OF A SINGLE SOURCE FOR MATERIAL QUANTITIES IN TENDERS

The diagnosis phase has revealed a final issue with the absence of a single source for material quantification. Currently, the process relies on various sources, manual data inputs, and data exchange between various software tools, including BIM, DuboCalc, and Excel. Particularly during the tender phase, where it has resulted in discrepancies as individuals work with different sets of material quantity figures. According to the interviews the goal would be to have a single, reliable source for material quantification. This strategic shift aims to diminish the need for manual data entry and reduce the potential for human errors. However, there are technical challenges preventing the realization of this vision. The intricacies and ever-changing nature of construction materials, along with the distinctive characteristics of each project, pose significant hurdles to seamlessly integrating MKI calculations into BIM models. This problem can be found in the SPM Model at the Resource Management dimension since this challenge involves technical hurdles related to material quantification, and addressing it requires reallocation of resources. Below in Figure 8 the location of each problem within the SPM model can be seen.

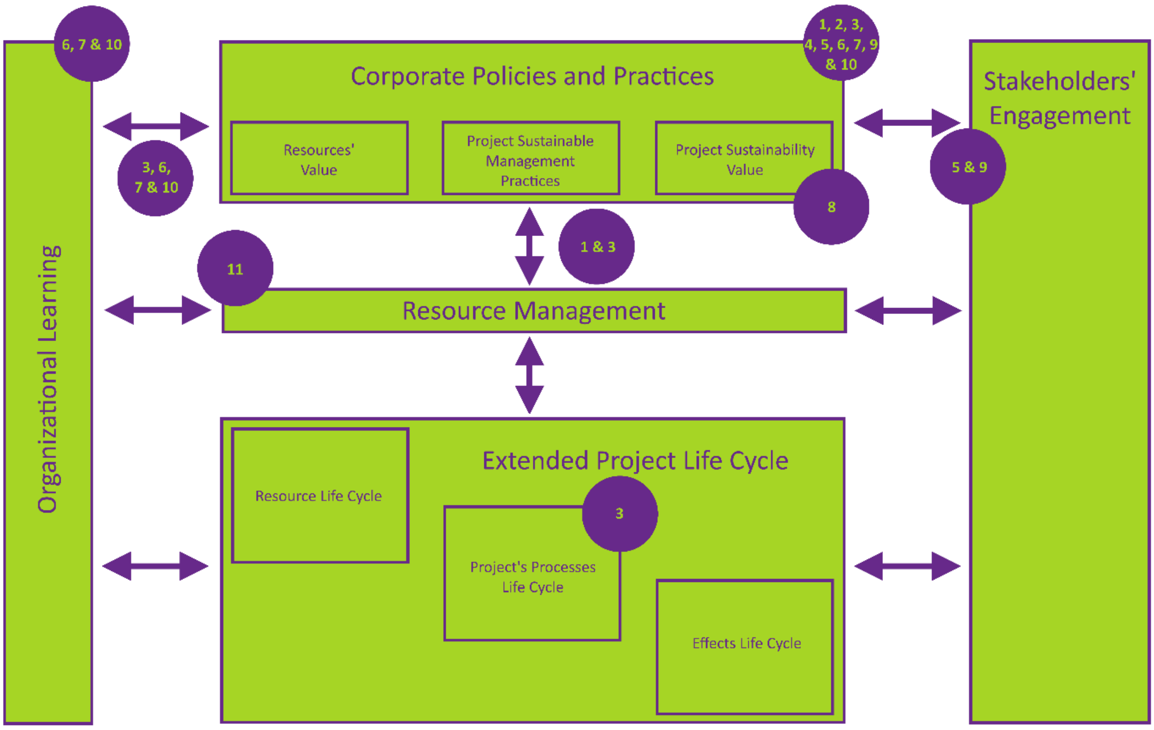


Figure 8 – Diagnosed Problems located in the Sustainable Project Management Framework

4.2 Objective Definition

After identifying the problems with the current processes, the subsequent activity involved outlining the objectives for the new MKI process at Mobilis TBI. The identified problems were systematically translated into actionable design principles, aligning with the structure outlined by Chandra et al. (2015). Based on problem 3, it was decided that the artifact would be most efficient when it would become a standardized process. The reason for this is that a standardized process would be capable of clearly indicating the responsibility and correct order of tasks for the entire calculation and for all involved personnel. Furthermore, many of the other problems could be solved as well according to the experts using a standardized process. The design principles have been written in such a manner that the objective could be achieved using a standardized process to solve the identified problem. Prior to the second focus group, these design principles were prepared and thereafter refined and finalized through collaborative efforts within the expert team during the second focus group, which is summarized in Appendix G. These principles serve as foundational guidelines that significantly influence the design of the new process. Furthermore, during the second focus group, experts applied the MoSCoW method to prioritize the design principles. A comprehensive summary of all results from the 'Objective Definition' activity within the DSRM is presented in Table 6.

Table 6 – Defined design principles and priority for all identified problems.

	Problems		Design Principles	Priority
1	Scope variability between projects	1	Enable with a standardized process for the creation of the (structured) definition of the MKI scope **(property)**, so that project teams can accurately determine the MKI scope **(activity)**, considering variability between the MKI scopes of projects due to requirements, preferences, and contractual obligations **(preconditions)**.	Should
2	Unstructured use of bandwidth determination	2	Enable with a standardized process for the creation of a decision-making moment for risk assessment related to the MKI **(property)**, so that project teams use acceptable risk levels when submitting tenders **(activity)**, considering EMVI benefits, penalties, and price fluctuations **(preconditions)**.	Should
3	Unclear responsibility and handover	3	Enable with a standardized process for the creation of a clear assignment of responsibilities and tasks **(property)**, so that project teams allocate responsibility and task execution to the appropriate individuals with clear lines of transfer **(activity)**, considering the strengths and weaknesses of different roles and functions **(preconditions)**."	Must
4	Lack of structured control of quantities	4	Enable with a standardized process for the creation of a standard approach for the control of material quantities **(property)**, so that project teams can consistently and accurately manage and control material quantities **(activity)**, considering the short time span during the tender phase **(preconditions)**.	Must
5	Lack of structured control of MKI during request of change	5	Enable with a standardized process for the creation of a control element of the MKI within a request to change **(property)**, so that project teams systematically incorporate the consequences of the request to change into the MKI-calculation **(activity)**, considering the current way requests of change are executed **(preconditions)**.	Must
6	Insufficient knowledge and experience with MKI	6	Enable with a standardized process for the creation of a moment for knowledge sharing **(property)**, so that project team members can acquire expertise and understanding of MKI **(activity)**, considering the current imbalance in knowledge distribution **(preconditions)**.	Won't
7	Lack of awareness regarding the existence of a LCA library	7	Enable with a standardized process for the creation of instructions for the use of the LCA library **(property)**, so that project teams are aware of the existence of the LCA library and can utilize it through the sustainability coordinator **(activity)**, considering that the sustainability coordinator always has an advisory role in this activity **(preconditions)**.	Should
8	Environmental goals Mobilis TBI	8	Enable with a standardized process for the creation of input for defining internal MKI objectives **(property)**, so that project teams can align with internally imposed sustainability goals **(activity)**, considering more effective measurement, mitigation of the environmental impacts of construction projects, and the profit motive **(preconditions)**.	Must
9	Limited client emphasis on environmental impact in procurement	9	Enable with a standardized process for the creation of consultation moments with the client in the design process **(property)**, so that project teams can validate and verify environmentally conscious design decisions with the customer **(activity)**, considering conflicts between aesthetic, technical, and sustainability requirements **(preconditions)**.	Should
10	Lack of project focused employees for MKI	10	Enable with a standardized process for the creation of a transformation plan to promote a project-focused culture **(property)**, so that project teams can embrace project-oriented approaches **(activity)**, considering the current way of working **(preconditions)**.	Won't
11	Lack of single source for material quantities in tenders	11	Enable with a standardized process for the creation of a centralized material quantity determination **(property)**, so that project teams can extract quantities from a single model **(activity)**, considering the current technological capabilities **(preconditions)**.	Could

The creation of the design principles and their prioritization elaborated in Table 6 yielded several key findings. First, design principles 3,4,5, and 8 were prioritized as 'must have' principles, requiring immediate attention and resolution. The significance of these principles lies in their impact on the efficiency of the to be developed artifact, as indicated by experts during the second focus group. Design principle 3 is of great importance as this principle should address the unclarity regarding the responsibilities for each task to be conducted during the MKI calculation. Similarly, principles 4 and 5 are important due to the potential of receiving fines from the client due to improper execution of these tasks. Both the use of incorrect material quantities and not implementing the MKI during the contractual changes are issues which must be resolved during the creation of the new artifact. Finally, the experts indicated that design principle 8 is a 'must have' design principle. In the interviews conducted during the problem identification it was indicated that calculating the MKI for each project necessitates prescribing project specific goals from Mobilis TBI to justify the calculation of the MKI during projects. Without such directives the invested time and effort into calculating the MKI would become unjustifiable.

On the contrary, design principles 6 and 10 were classified as 'won't have' design principles, as the experts believed these problems could not be resolved through the implementation of a new artifact, which focuses on the must have design principles. These issues would necessitate alternative solutions, such as updated training programs or accumulating experience from working on diverse projects utilizing the MKI. Therefore, these problems were not considered in the further development of the new MKI artifact. Based on the conducted interviews of the problem identification activity it would be recommended to implement MKI as an agenda point during kick-off meetings for each project phase to indicate to the project members what the important aspects are for each specific project. Furthermore, continuing with the conducted trainings would be recommended. However, this training should be updated with the implementation of the new artifact and further in-depth training could be given to employees directly involved in the execution of the artifact created in this research.

4.3 Design & Development

Advancing in the systematic approach of the DSRM, the design principles underwent further refinement and translation into design features. Design features are specific artifact capabilities designed to fulfill the design principles (Meth et al., 2015). Each design feature is a tangible aspect which will be implemented into the to be developed standardized MKI process, contributing to the resolution of the identified problems. This method not only facilitates a more accurate understanding of the design choices made but also enables the traceability of the rationale behind these choices. A comprehensive overview of all design principles and design features can be found in Table 7.

The process of creating the design features was informed by insights gathered from the interviews and the first and second focus groups if available, ensuring that the chosen features are practical and applicable to real-world scenarios. For example, in conformation with design principle 3, which emphasized the need for standardization, the design features were created to match Mobilis TBI's currently existing process environment. This is done to make sure the to be developed process is standardized across all processes at Mobilis TBI. Moreover, during expert interviews, several employees suggested different additional tasks. They made these suggestions based on the problems they identified and gave their opinion on how these problems might be resolved. After evaluating these suggestions against the established design principles, those deemed promising were incorporated as design features. Notable examples include features 1.1, 2, and 5. Expert input during the focus groups also played a significant role in shaping certain design choices, particularly for principles 5 and 8. Experts provided valuable insights, suggesting possible design features that could effectively fulfill the intended design principles. Furthermore, the researchers' expertise played a pivotal role in crafting design features that were deemed capable of achieving the desired outcomes aligned with the design principles. This approach ensured that the selected features were not only theoretically sound but also practically feasible within the context of the project's objectives and constraints.

Table 7 – Design features translated from the defined design principles

	Design Principles			Design Features
1	Enable with a standardized process for the creation of the (structured) definition of the MKI scope **(property)**, so that project teams can accurately determine the MKI scope **(activity)**, considering variability between the MKI scopes of projects due to requirements, preferences, and contractual obligations **(preconditions)**.	Should	1.1	Implement a task where the MKI-scope is defined in the initiation phase.
			1.2	Implement a task where it is checked by the project team if the scope defined in the initiation phase is still accurate with the current state of the project.
2	Enable with a standardized process for the creation of a decision-making moment for risk assessment related to the MKI **(property)**, so that project teams use acceptable risk levels when submitting tenders **(activity)**, considering EMVI benefits, penalties, and price fluctuations **(preconditions)**.	Should	2	Implement a task in the initiation phase where it is decided what bandwidth should be used for the tender bid.
3	Enable with a standardized process for the creation of a clear assignment of responsibilities and tasks **(property)**, so that project teams allocate responsibility and task execution to the appropriate individuals with clear lines of transfer **(activity)**, considering the strengths and weaknesses of different roles and functions **(preconditions)**."	Must	3.1	The process should follow a logically sequenced order in performing the necessary tasks for all phases.
			3.2	The process should indicate the RASCI of the necessary tasks clearly for all phases.
4	Enable with a standardized process for the creation of a standard approach for the control of material quantities **(property)**, so that project teams can consistently and accurately manage and control material quantities **(activity)**, considering the short time span during the tender phase **(preconditions)**.	Must	4.1	Implement a task where the quantities of the design are controlled in the initiation phase.
			4.2	Implement a task where the quantities of the design are controlled in the planning/realization phases.
5	Enable with a standardized process for the creation of a control element of the MKI within a request to change **(property)**, so that project teams systematically incorporate the consequences of the request to change into the MKI-calculation **(activity)**, considering the current way requests of change are executed **(preconditions)**.	Must	5	Implement an extra indication that the MKI should be checked during a change of contract.
6	Enable with a standardized process for the creation of a moment for knowledge sharing **(property)**, so that project team members can acquire expertise and understanding of MKI **(activity)**, considering the current imbalance in knowledge distribution **(preconditions)**.	Won't	-	-
7	Enable with a standardized process for the creation of instructions for the use of the LCA library **(property)**, so that project teams are aware of the existence of the LCA library and can utilize it through the sustainability coordinator **(activity)**, considering that the sustainability coordinator always has an advisory role in this activity **(preconditions)**.	Should	7.1	Implement a task where the impact of the design is analyzed in order to see which design parts have the highest impact which could be mitigated.
			7.2	Implement a task where it is checked whether there are MKI-values which can be extracted from the LCA library for the design of the current project.
8	Enable with a standardized process for the creation of input for defining internal MKI objectives **(property)**, so that project teams can align with internally imposed sustainability goals **(activity)**, considering more effective measurement, mitigation of the environmental impacts of construction projects, and the profit motive **(preconditions)**.	Must	8	Create a input in which the MKI goals from Mobilis TBI are integrated.

9	Enable with a standardized process for the creation of consultation moments with the client in the design process **(property)**, so that project teams can validate and verify environmentally conscious design decisions with the customer **(activity)**, considering conflicts between aesthetic, technical, and sustainability requirements **(preconditions)**.	Should	9	Implement a moment in the process where it is decided on whether communication with the client is necessary in regards to the MKI requirements.
10	Enable with a standardized process for the creation of a transformation plan to promote a project-focused culture **(property)**, so that project teams can embrace project-oriented approaches **(activity)**, considering the current way of working **(preconditions)**.	Won't	-	-
11	Enable with a standardized process for the creation of a centralized material quantity determination **(property)**, so that project teams can extract quantities from a single model **(activity)**, considering the current technological capabilities **(preconditions)**.	Could	11	Implement an indication in which it is stated that the quantities of the design are ideally centralized in one source.

Thereafter, the actual artifact of this research, the new MKI process, was designed using the design principles and design features. While designing the new process, the decision was made to create two distinct processes, each tailored to accommodate the unique requirements of different construction phases. The first process can be used for the initiation phase of the project, while the second process is tailored towards the planning and realization phases of projects. The decision to create two separate processes is driven by the recognition that a project during procurement necessitates significantly different actions and sequence of actions in comparison with the process during the planning and realization phases of the project. For example, actions necessary during a change of the contract are not relevant for the process during procurement, given the absence of a formalized contract at that stage. The adoption of two separate processes ensures that the specific needs and considerations of each phase effectively addressed.

During the development of the new MKI processes, the design features underwent transformation into the new processes aligned with the Sensus methodology, as detailed in Section 3.3.3. Each design feature was carefully examined to determine how it could be translated into the Sensus Method, resulting in the creation of Sensus Method Design Features. Subsequently, these features were organized alongside additional actions and required input documents essential for the MKI-calculation process. This iterative process created conceptual versions of both the initiation MKI-process and the planning/realization MKI-process. Table 8 displays the implemented Sensus method design features corresponding to each design feature.

Table 8 – Sensus method design features used to implement the defined design features into the new MKI process

Design Features		Sensus Method Design Feature	
1.1	Implement a task where the MKI-scope is defined in the initiation phase.	1.1	Action: 'Determine scope MKI' in the initiation process.
1.2	Implement a task where it is checked by the project team if the scope defined in the initiation phase is still accurate with the current state of the project.	1.2	Action: 'Check correctness of MKI scope' in the planning/realization process.
2	Implement a task in the initiation phase where it is decided what bandwidth should be used for the tender bid.	2	Action: 'Determining opportunities and risks MKI' in the initiation process.
3.1	The process should follow a logically sequenced order in performing the necessary tasks for all phases.	3.1a	The tasks, input documents, etc. are logically sequenced following the Sensus-method in the initiation process.
		3.1b	The tasks, input documents, etc. are logically sequenced following the Sensus-method in the planning/realization process.
3.2	The process should indicate the RASCI of the necessary tasks clearly for all phases.	3.2a	RASCI is used to indicate the responsibility, accountability, etc. where necessary for each task in the initiation process.
		3.2b	RASCI is used to indicate the responsibility, accountability, etc. where necessary for each task in the planning/realization process.
4.1	Implement a task where the quantities of the design are controlled in the initiation phase.	4.1	Action: 'Check final quantities' in initiation process.
4.2	Implement a task where the quantities of the design are controlled in the planning/realization phases.	4.2	Description in action 'Update material quantities' in the planning/realization process, where is described that after gathering the material quantities for the design should be checked.
5	Implement an extra indication that the MKI should be checked during a change of contract.	5	Description in the change of contract process (so, neither of the MKI processes) for a check whether the change of contract has influence on the MKI aspect of the project.
7.1	Implement a task where the impact of the design is analyzed in order to see which design parts have the highest	7.1a	Action: 'Perform MKI impact analysis' in initiation process.
		7.1b	Action: 'Perform MKI impact analysis' in planning/realization process.
7.2	Implement a task where it is checked whether there are MKI-values which can be extracted from the LCA library for the	7.2a	Action: 'Check for existing LCA's' in initiation process.
		7.2b	Archive: 'LCA Library' in initiaton process.
		7.2c	Archive: 'LCA Library' in planning/realization process.
8	Create a input in which the MKI goals from Mobilis TBI are integrated.	8a	Document: 'MKI goal Mobilis' in initiation process.
		8b	Document: 'MKI goal Mobilis' in planning/realization process.
9	Implement a moment in the process where it is decided on whether communication with the client is necessary in regards to the MKI requirements.	9a	Choice: 'Unclarities in tender?' in initiation process. In case this question is true: Action: 'Request note of information to client'.
		9b	Choice: 'Unclarities in contract?' in planning/realization process. In case this question is true: Action: 'Consult with client'.
11	Implement an indication in which it is stated that the quantities of the design are ideally centralized in one source.	11a	Description in action: 'Determine material quantities design' in initiation process which indicates that if possible the quantities should be centralized into one source.
		11b	Description in action: 'Update material quantities' in planning/realization process which indicates that if possible the quantities should be centralized into one source.

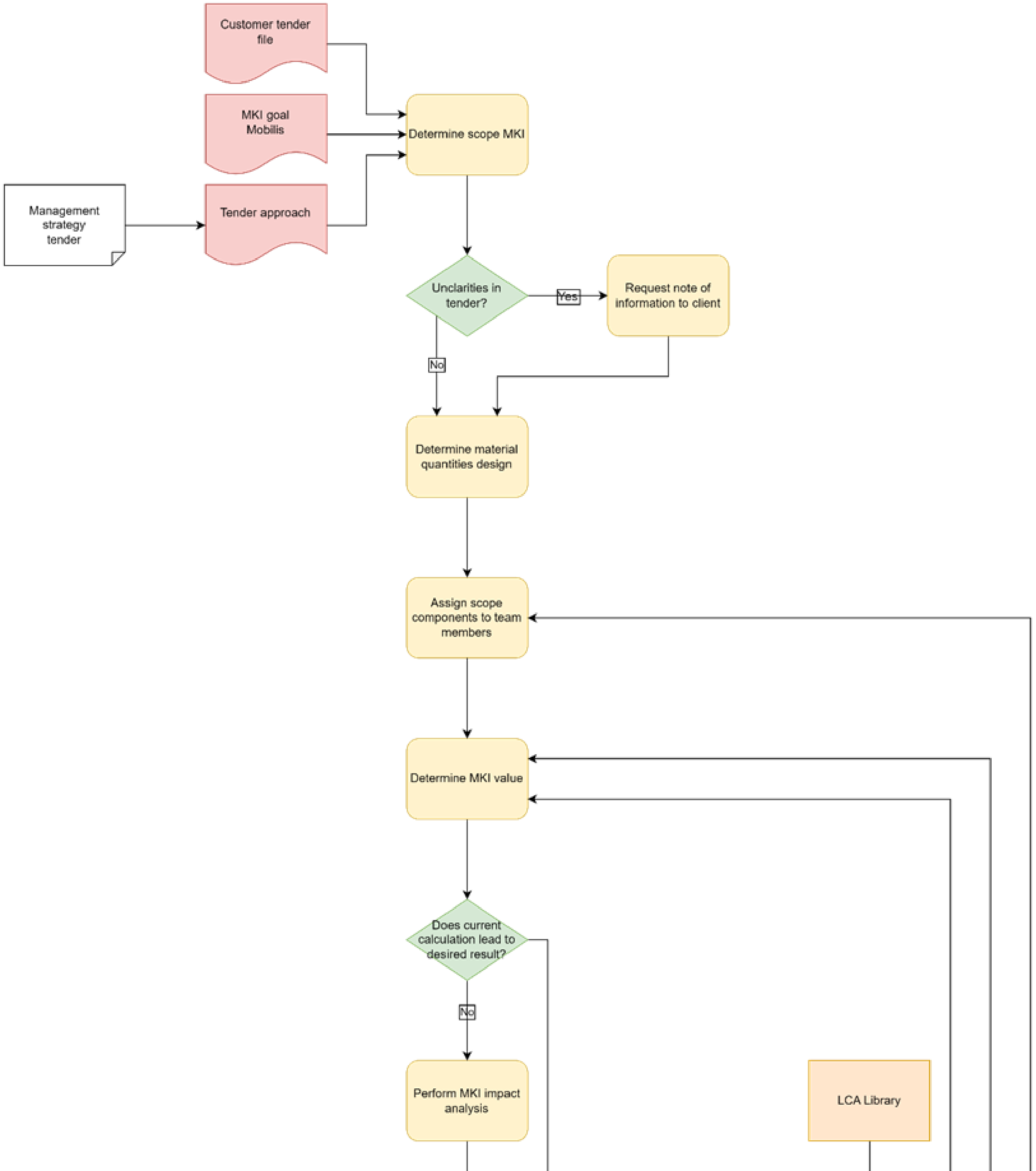
4.4 Demonstration

The demonstration of the artifact, in the form of the new MKI process, developed in this research took place during the third and concluding focus group. In this session, both the conceptual initiation and planning/realization MKI processes were elaborated upon. During this focus group both developed processes were systematically navigated step by step. The goal of this demonstration was to ensure the logical sequence of all process steps and the accuracy of the descriptions and the RASCI. During the third focus group valuable insights were gathered from the experts through collaborative efforts, leading to substantial refinements which transformed the conceptual process into the final MKI process. Within this Section the important adjustments are elaborated. Further elaboration of the changes and additions made to the final MKI process can be found in the summary of the third focus group which can be found in Appendix H.

The biggest adjustment which was made during the third focus group to the newly developed conceptual MKI process was the proposal for an additional action and choice moment to be added in the initiation MKI process. This additional action involves an analysis of the projects MKI value only using the standard DuBoCalc values from the NMD database as elaborated in Section 2.2. Following this action, a choice is implemented which is used to determine whether or not the design already meets the desired outcome. This addition to the process is made based on the input of the experts who stated that it is possible to meet the desired standards in regard to the MKI value without optimizing the design solution or using product specific LCA's.

Another suggestion made by the experts was renaming two documents from 'MKI goal customer' to 'Customer tender file' and 'MKI calculation tender' to 'MKI tender report'. Both of these changes were made as these names better represent the actual document which is used in the process. Also, the names of the actions, 'Request note of information to client', 'Assigning scope parts to team members', and 'Determining opportunities and risks MKI', were slightly reevaluated. Other refinements of the conceptual process include the implementation of an additional input process in the planning/realization process and the revaluation of several responsibilities and supporting roles within the RASCI of the different process steps in both processes.

The final MKI processes based on the adjustments made during the third focus group are outlined in Figure 9 for the initiation process and in Figure 10 for the planning/realization process. The process as it is implemented into the Prosizer of Mobilis can be seen in Appendix I for the initiation process and Appendix J for the planning/realization process. This process is in Dutch and includes detailed descriptions of the RASCI Matrices for both processes.


Customer tender file
MKI goal Mobilis
Management strategy tender
Tender approach
Determine scope MKI
Unclarities in tender?
Yes
Request note of information to client
No
Determine material quantities design
Assign scope components to team members
Determine MKI value
Does current calculation lead to desired result?
No
Perform MKI impact analysis
LCA Library

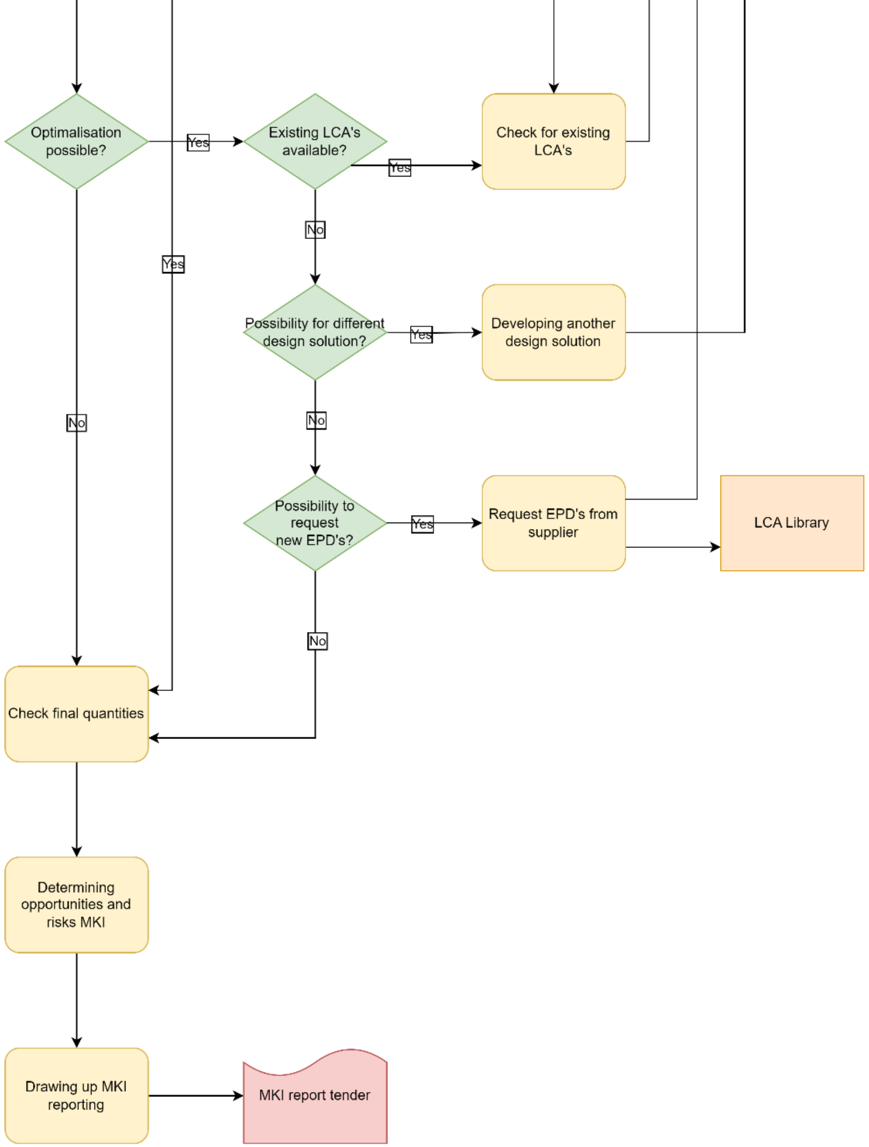
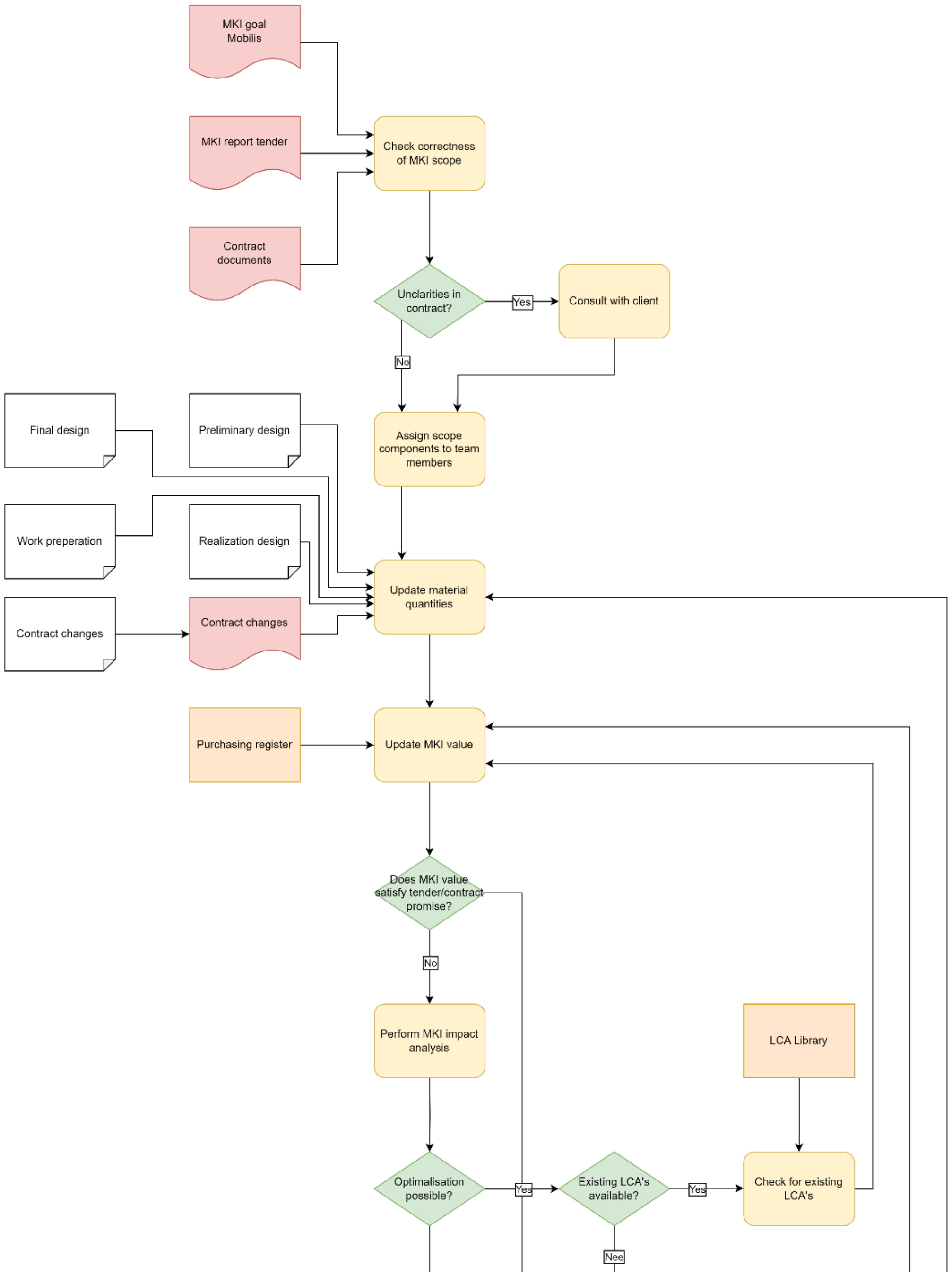


Figure 9 – Final MKI process for initiation phase


MKI goal Mobilis
MKI report tender
Contract documents
Check correctness of MKI scope
Unclarities in contract?
Yes
Consult with client
No
Final design
Preliminary design
Assign scope components to team members
Work preperation
Realization design
Update material quantities
Contract changes
Contract changes
Purchasing register
Update MKI value
Does MKI value satisfy tender/contract promise?
No
Perform MKI impact analysis
LCA Library
Optimalisation possible?
Yes
Existing LCA's available?
Yes
Check for existing LCA's
Nee

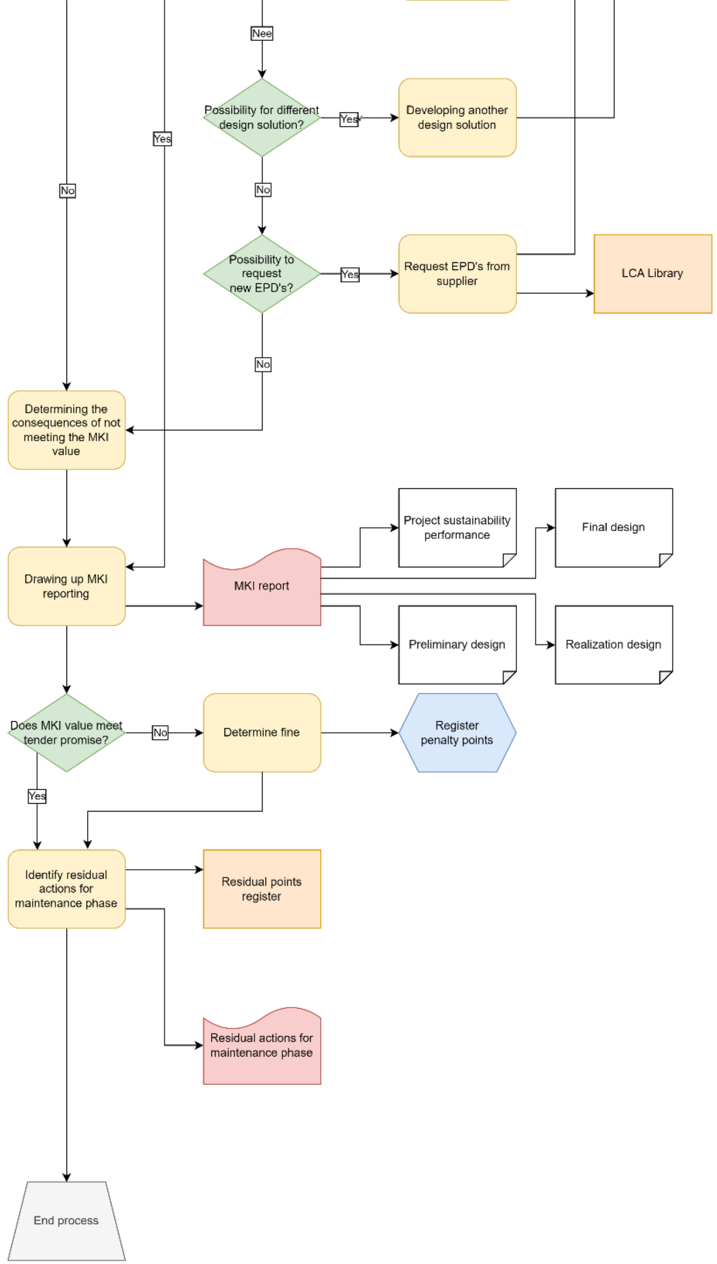


Figure 10 – Final MKI process for planning and realization phases

4.5 EVALUATION

During the third focus group, an evaluation was conducted to assess the effectiveness of the employed solutions in addressing the identified problems. This evaluation was conducted based on four criteria, namely, operationality, efficiency, generality, and ease of use (Gonzalez & Sol, 2012; March & Smith, 1995). Through utilization of a Likert scale, the experts from the third focus group provided ratings for each problem and criterion, yielding insightful findings. Within this Section the findings from the evaluation are elaborated upon, with the data summarized in Table 9.

Among the addressed problems, namely 1,2,3,4, and 7, were addressed adequately across each of the four criteria's according to the experts. However, underlying uncertainties surfaced during the evaluation, particularly concerning the practical implementation of the solutions. Some of the experts had apprehensions concerning the consistent adherence of employees to specific tasks within the newly developed process, signaling potential challenges in organizational adoption and integration. The emergence of these apprehensions can be attributed to the fact that several tasks integrated into the newly developed process to address the identified issues are new to the employees tasked with its use. Consequently, it is imperative that these employees are provided with clear and comprehensive explanations regarding the rationale behind the execution of specific tasks. Problem 8, which was addressed by incorporating Mobilis MKI goal input document, received positive feedback. Even though the problem was evaluated positively concerns were raised regarding its practical implementation in projects due to the absence of clearly defined objectives. These objectives are important for the effective creation of more sustainable projects. One of the problems which received a lower evaluation is problem 5. Resolution of this issue was planned to be achieved by modifying the change of contract process. However, at the time of the third focus group this modification was not yet executed, leading to a lower evaluation. Furthermore, experts indicated partial resolutions of problem 9 by the introduction of the actions 'Request note of information to client' and 'Consult with client' in the initiation and planning/realization processes respectively. The inclusion of these two actions facilitates the possibility of dialogue with the client in the case of unclarities in contract requirements. However, this problem was evaluated slightly below average because the clients' priorities, actions, or requirements cannot be changed with the introduction of the new MKI process. Problem 11 has been addressed by expressing the intention to gather material quantities in one source, but further implementation of a single source for material quantification necessitates additional research, explaining the lower evaluation. For the last two issues, problems 6 and 10, the decision was made during the second focus group to forego immediate solutions, with a focus on long-term improvements through the creation of this new MKI process. Therefore, evaluation for these problems is not applicable. In Appendix K the complete process from identified problem to implemented Sensus features, and evaluation of the problems can be seen for each of the identified problems.

During this evaluation a notable pattern emerged as the problems effectively addressed were primarily categorized within the corporate policies domain of the SPM framework, while those outside this category received lower evaluations. Problem 9, influenced by stakeholders, and problem 11, impacted by technological resource limitations, posed challenges beyond procedural changes in Mobilis TBI's corporate policies. Problem 5, although influenced by Mobilis TBI's policies, was tied to a different process than the focus of this research, resulting in a lower rating. This underscores the effectiveness of structured processes in addressing corporate policy-related challenges.

Table 9 – Evaluation of employed solutions of identified problems (5 = excellent, 4 = good, 3 average, 2 = fair, 1 = poor)

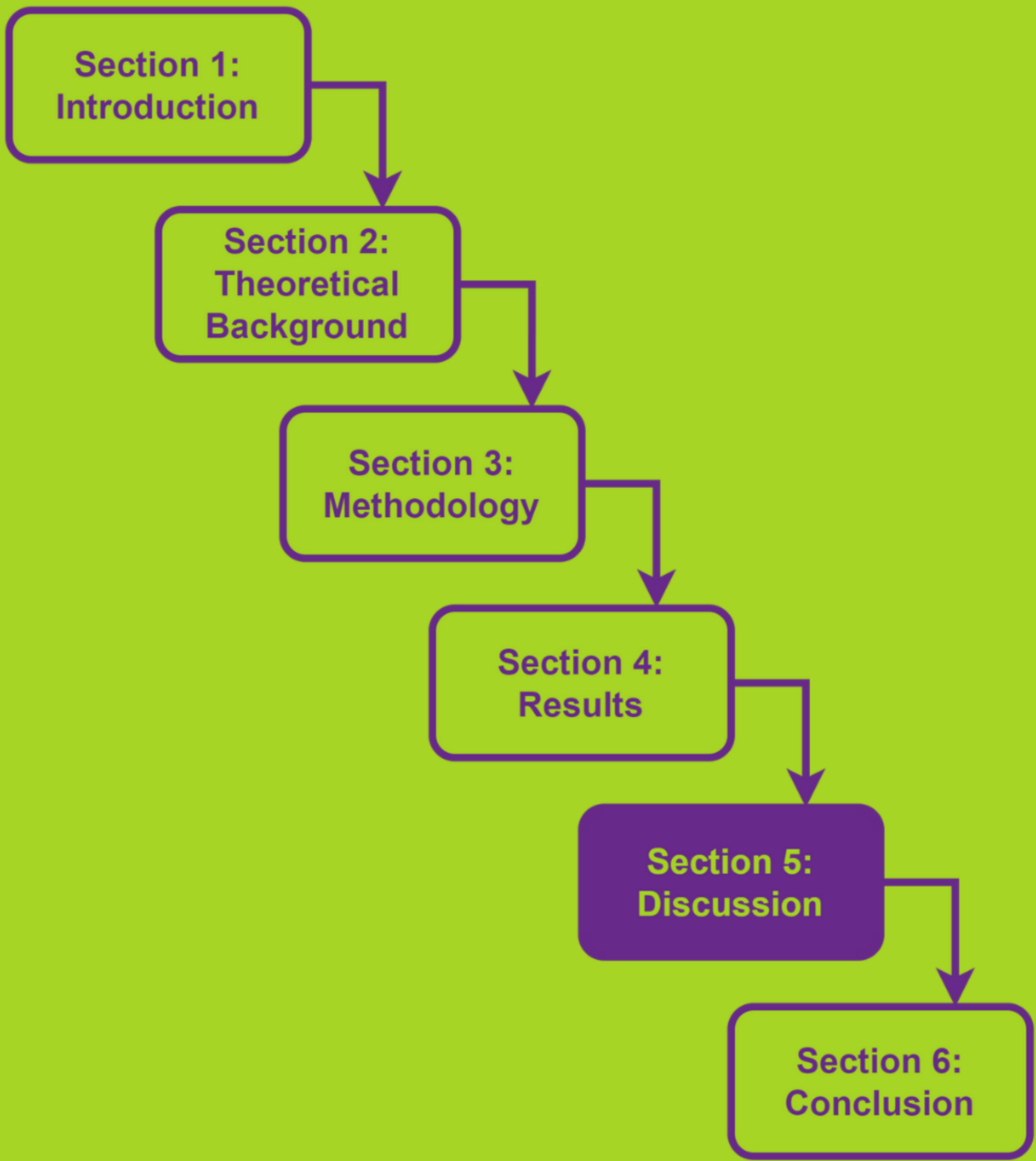
	Problem	Evaluation			
		Operationality	Efficiency	Generality	Ease of Use
1	Scope variability between projects	3	4	5	3
2	Unstructured use of bandwidth determination	4	4	5	3
3	Unclear responsibility and handover	5	5	5	5
4	Lack of structured control of quantities	5	4	5	4
5	Lack of structured control of MKI during request of change	2	2	1	1
6	Insufficient knowledge and experience with MKI	-	-	-	-
7	Lack of awareness regarding the existence of a LCA library	4	4	4	4
8	Environmental goals Mobilis TBI	4	4	3	3
9	Limited client emphasis on environmental impact in procurement	2	2	3	2
10	Lack of project focused employees for MKI	-	-	-	-
11	Lack of single source for material quantities in tenders	2	1	2	1

4.6 Communication

The final activity of the Design Science Research Methodology (DSRM) involves effectively communicating the research findings to stakeholders. In the context of this study, the communication of results is crucial for two primary groups: the intended audience for the research and the employees at Mobilis TBI who need insights into the functionality of the developed artifact. The first target audience encompasses those individuals directly involved or interested in the research topic addressed in this report. This audience is provided with this research report, giving a comprehensive understanding of the research objectives, methodologies employed, and the key findings. This ensures that the research is not only transparent but also accessible.

The second audience consists of Mobilis TBI employees, who need to familiarize themselves with the intricacies of the newly developed artifact from this research. To facilitate this understanding an implementation plan has been developed. Within this plan, a short elaboration of the objectives for the new process and its implementation are given. The first step of the implementation plan is an elaboration of the identified problems which were the reason for the creation of this process. Thereafter it is elaborated how it is attempted for these identified problems to be resolved and the points of interest which should be known by the employees regarding the designed solutions for these problems. Also, possible unresolved issues are elaborated upon, or additional information is given for issues which have been partially resolved. Subsequently, the risks identified during the research are elaborated, offering an analysis of potential challenges associated with the implementation of the artifact. Finally, a step-by-step implementation plan is outlined. This detailed plan serves as a guide, presenting actionable steps to mitigate the identified risks and ensure the successful implementation of the new MKI-process. This implementation plan functions as a proactive tool to address potential hurdles and thereby maximizing the probability of an effective and efficient implementation of the newly designed MKI-process. The full implementation plan can be found in Appendix L.

In this discussion, the findings of the research are closely examined, aiming to interpret their relevance within the existing body of literature. The discussion highlights the significance of these findings and acknowledges the limitations of the study, offering a clear understanding of its scope and potential constraints.



DISCUSSION

5 Discussion

This study was initiated at the request of Mobilis TBI in response to the absence of a standardized process for calculating the MKI. The lack of a consistent approach to the MKI calculations had given rise to several challenges, including a lack of awareness of the MKI, calculation inconsistencies leading to errors, and irregular updates in the calculation process. These challenges have not only exposed the company to financial penalties but have also hindered the realization of potential opportunities for developing more sustainable projects. The application of DSRM in this study facilitated the identification of challenges associated with the MKI calculations in the established MKI-calculation process. Additionally, the research produced essential design principles that facilitated the integration of the MKI-calculations. The culmination of these efforts is the development of an artifact designed to address the identified challenges within Mobilis TBI.

Interpretation of Findings

This research contributes to the existing literature by providing a comprehensive understanding of the critical considerations involved in incorporating LCA calculations, specifically the MKI in this research, within the established construction processes. In the existing literature notable advancements have been made towards developing methods to integrate the calculation of LCA into the design process of construction projects (Cavalliere et al., 2019; Scherz et al., 2022; Soust-Verdaguer et al., 2017). However, as mentioned in Section 2.4 these methods are not generalizable in practice for different calculation methods as well as different project phases (Jalaei & Jrade, 2014; Naneva et al., 2020). In response, this research aimed to consider the project management aspect of construction projects to standardize the calculations of an LCA. The utilization of the SPM framework in this research allows for a nuanced exploration of the challenges that may arise and the influences of these problems on construction projects.

The initial activity of this research tried to identify the most significant issues with the existing process used for the calculation of the MKI. During this activity an interesting pattern emerged as the identified problems at Mobilis TBI were mostly categorized within the corporate policies category of the SPM framework. This pattern suggest that the challenges faced by Mobilis TBI are primarily rooted in the internal policies of the company rather than external factors such as stakeholders, the implementation of technology, or employee training. This finding aligned with Mobilis TBI's initial inquiry, where they sought a change in their policies by proposing a new MKI-calculation process. Upon further analysis of the problem identification using the SPM framework, it becomes evident that the policies of contractors play a pivotal role in enhancing sustainability measurement. Incorrect utilization of corporate policies can lead to disruptions in the effective and efficient measurement of sustainability, exemplified by Mobilis TBI facing fines consequently. This underscores the critical importance of aligning corporate policies with sustainability goals for accurate and successful measurements.

Following the identification of the problems, a systematic approach was taken to address these problems. This involved the sequential creation of design principles, design features, and ultimately the final artifact, which incorporates these design principles. Subsequently, an evaluation was conducted to assess the effectiveness of the artifact in resolving the identified issues from the problem identification activity. During the evaluation, another pattern emerged as the problems that had been targeted for resolution and were deemed as adequately addressed were predominantly categorized within the corporate policies category of the SPM framework. The three problems, namely 5, 9 and 11, which were not mainly categorized in corporate policies received considerably lower evaluations. problem 9 is influenced by stakeholders as the client determines bidding requirements, and problem 11 is mainly affected by a lack of technological resources, posed challenges that could not be immediately mitigated by altering Mobilis TBI's corporate policies through a procedural change. Problem 5 is directly influenced by the corporate policies of Mobilis TBI, however is influenced by a different process than the MKI process on which was focused during this research. Since this process was not yet altered during the evaluation this problems solution received a lower rating. A similar reasoning applied to problem 8, where goals for each project needed definition, an aspect not within the scope of the MKI process. By implementing the goals in the MKI-process as input the hope is that these MKI-goals will be defined by the direction of Mobilis TBI. Notably, the successfully solved problems, problem 1,2,3,4, and 7, were all mainly categorized in the corporate policies of the SPM framework. Based on the insight gained from the evaluation activity within the Design Science Research Methodology (DSRM), it becomes apparent that instituting a structured process proves to be an effective solution for addressing issues within the corporate policies aspect of the SPM framework.

Contributions to Literature

This research holds substantial significance within the existing literature on sustainability measurement in construction projects. As elaborated in the Theoretical Background in Section 2, current research mostly focuses on the implementation of LCA techniques using BIM (Cavalliere et al., 2019; Llatas et al., 2020). This research instead focused on the project management aspect integrated with sustainability to improve the measurement of sustainability. For this research the SPM framework was used created by Armenia et al. (2019). First, the identified challenges uncovered during the problem identification phase of this study may have broader implications for other companies and various LCA-based calculation methods. This research is the first research to identify challenges for measuring sustainability using a Sustainable Project Management perspective. Should other case studies use the SPM perspective, as done in this research, and encounter similar challenges as witnessed by Mobilis TBI, there is potential for quicker identification of these challenges and the possibility to leverage the design principles or features derived from this research. However, while the issues are universal, the feasibility of the solutions require careful consideration of the unique nuances within each organizational context.

As stated, previous research mostly looked at sustainability measurement from a technical angle. However, when using the SPM perspective a holistic view is necessary, incorporating aspects such as organizational learning and stakeholders (Blais & Agbodoh-Falschau, 2023; Kivilä et al., 2017). By taking this holistic approach during this research, this research underscores the pivotal role played by contractors in advancing sustainability measurement, primarily through the influence on corporate policies. Despite the evaluation being conducted prior to any test case or real-world implementation, it is evident that establishing a comprehensive process proves to be an effective solution for addressing identified issues within the corporate policies category of the SPM framework. This finding suggests that contractors possess significant influence in shaping and refining sustainability measurements within projects. Nevertheless, it is essential to acknowledge that in situations where technical aspects, stakeholder considerations, or learning capabilities take precedence, alternative solutions may be more advantageous.

Furthermore, Armenia et al. (2019) indicated in their paper that the SPM framework should be used for case studies to show the framework has added value in research. This research showed that the interconnected SPM framework gave insightful findings regarding the issues and possible solutions for this specific case. Thereby this framework showed its value for its use in case studies in research. An additional noteworthy finding is the acknowledgment that, despite the efficiency of creating a process as a solution for corporate policy challenges, exclusively relying on either process creation or the focus on technical aspects as is the case in current sustainability literature is not a comprehensive solution. Recognizing the interconnected nature of all categories within the SPM framework is important. To ensure effective and efficient sustainability measurement in projects, it is crucial not only to have well-established corporate policies but also to ensure client commitment to sustainable construction, adequately trained and experienced employees, and the availability of appropriate technologies. Each category within the SPM framework plays an essential role in enhancing sustainability measurement. As highlighted by Mavi et al. (2021), the act of measuring sustainability not only provides a basis for improvement but also presents opportunities for implementing other sustainable practices such as lean construction, circularity, or the integration of newly developed materials. So, for projects to become more sustainable, it is important for companies to consider all categories of the SPM framework when measuring the sustainability of a project.

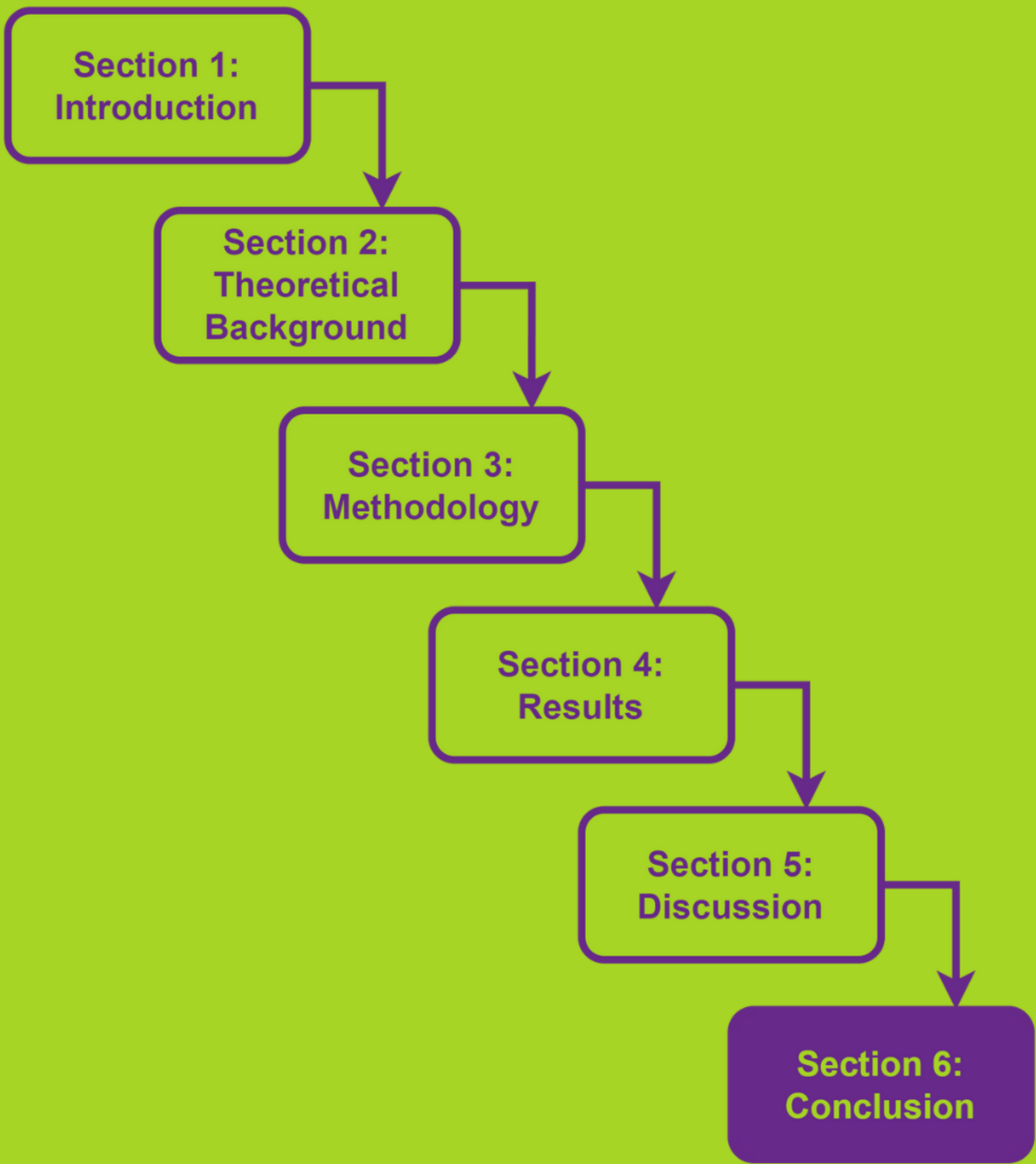
Limitations of Research

While the proposed solution demonstrated positive results in addressing the specific challenges within Mobilis TBI's corporate policies of the SPM framework, caution is warranted when extending these findings to other organizational contexts. This caution arises because the research exclusively considered the organizational context of Mobilis TBI, and the success observed within their unique challenges does not guarantee universal applicability. In situations where the nature of problems significantly differs, the current approach may not be transferable. The distinctiveness of sustainability challenges across diverse contexts may necessitate alternative methods, highlighting the importance of a nuanced and context-specific approach in addressing sustainability issues.

Moreover, the interviews conducted lacked a structured framework aligned with the SPM model. This lack of structure might have influenced the depth and consistency of the gathered information. Additionally, the absence of a participant in one of the expert groups led to certain aspects being unaddressed. To counterbalance this, a separate discussion with an expert in the relevant field was conducted to fill the knowledge gap, although this approach may have introduced variations in the data collection process. Furthermore, the intended modification of the contract change process, aimed at resolving Problem 5, was not executed by the third focus group. This incomplete implementation could have influenced the overall evaluation of the proposed solution for Problem 5. It is crucial to acknowledge that the evaluation may undergo changes as the modification is implemented, and its effects become observable.

Finally, some of the problems that this research had identified, have not, or not fully, been resolved. The reason for this is that creating a solution for these specific problems was not possible within the creation of a process, the artifact of this research. Problems such as the learning capabilities of the employees (problem 6), stakeholder impacts on the process (problem 8), and technical capabilities of improving for example the material quantities gathering process by using a single source (problem 11) were not deemed as resolved in this research. The interconnectedness of the SPM framework suggests that the best results for Mobilis TBI could be achieved when all the aspects of the SPM framework are implemented correctly. Therefore, it would be recommended that these problems receive further attention in subsequent research. Also, the SPM Framework's use could be further improved when testing the framework for organizational learning, stakeholder and technical capabilities and combining these to show the interconnectedness of the SPM Framework.

This conclusion summarizes the key findings from this research, addresses the main research question, and provides recommendations for future research.



CONCLUSION

6 Conclusion

In this study, which employs the Design Science Research Methodology, the primary aim was to establish scholarly rigor by addressing a design problem within Mobilis TBI's infrastructure projects. Before delving into the research questions, this conclusion first examines the design problem of this research. This research aimed to refine the integration of MKI calculations and supporting activities within Mobilis TBI's existing project processes. The design problem for this design science research was defined as: Refine the integration of the MKI calculations and supporting activities in the currently existing processes for projects of Mobilis TBI by designing a new process for calculating the MKI which satisfies the aim to be standardized, auditable, and clear.

To address this design problem, this research was conducted, resulting in the development of two new processes intended for implementation within existing workflows. One process targets the initiation phase of projects, while the other focuses on the planning and realization phases. Since this process should be executed the same for each project this process is standardized. Also, because the steps should be executed the same for each project, these steps can be controlled and is therefore auditable. Finally, the solution integrated into the process for design principle 3 ensures that the process is clear.

Delving deeper in the conducted research, this research aimed to address the main research question, which was subdivided into six sub-questions, each aligned with a specific activity of the DSRM. The first sub-question involved conducting an analysis of the current situation at Mobilis TBI. This analysis drew from various sources, including literature, project documentation, and expert interviews, to identify potential issues with the sustainability measurement process. Through this exploration, this analysis uncovered eleven distinct problems with the current process, with many falling under the corporate policies category of the SPM framework. These findings provided valuable insights into the challenges associated with establishing a standardized MKI calculation process.

With a comprehensive understanding of the challenges associated with the creation of a new MKI-process, the subsequent phase entailed defining objectives for creating a standardized MKI calculation process. This activity drew upon the collective expertise of the expert team during the second focus group. Subsequently, these objectives were translated into tangible design features, integrated into the new MKI process, serving as the final artifact of this research. Following the conceptualization of the artifact, a demonstration was conducted during focus group 3 with the aim of identifying necessary adjustments and refinements. These insights were then incorporated into the final artifact. Based on this final artifact it was evaluated whether the identified problem had been effectively addressed and resolved through the creation of the newly developed artifact. It was found that the solution was deemed effective for problems categorized under the corporate policies category. However, two problems remained unresolved, while two others, categorized as resource or stakeholder issues, saw suboptimal solutions. For the final sub-question, it was determined that the optimal method of communicating the research findings to relevant audiences was through the creation of this thesis report and an accompanying implementation plan, intended to facilitate the integration of the newly developed process.

Finally, by answering the six sub-questions this research aimed to address the main research question: What are the essential considerations for incorporating MKI calculation into existing construction processes in infrastructure projects across the initiation, planning, and realization phases? First, this research revealed several challenges applicable to measuring sustainability in construction projects, many of which fell under the corporate policies category of the SPM framework, indicating the significant influence of contractors in sustainable measurement calculations. However, it was also observed that addressing only one category of the SPM framework may not suffice in resolving all challenges encountered by a company in sustainability measurement. Therefore, this underscores the importance of ensuring alignment across all categories of the SPM framework. These findings highlight the need for further research in this area to explore comprehensive solutions that address the intricacies of sustainability measurement in infrastructure construction projects for all categories of the SPM framework instead of only one category as has happened in this research and the research as elaborated in the literature review.

This final finding also leads to the recommendations for future research. First, it is crucial for Mobilis TBI to prioritize the execution of the implementation plan outlined within this research. The successful implementation of the newly devised processes is important for fully realizing their potential in measuring sustainability within infrastructure construction projects. An essential aspect of this implementation is to assess the functionality of the newly developed process, thereby validating the findings of this research regarding the SPM framework. Furthermore, it is essential to conduct similar research across multiple companies to validate the findings of this study in diverse organizational contexts.

In addition to implementation and validating the research findings, future research efforts should concentrate on exploring potential adjustments to further refine the integration of sustainability measurement into existing processes across various categories of the SPM framework. One promising aspect is investigating the feasibility of utilizing a single source for gathering the material quantities of a project and possibly directly integrating it into the MKI calculation. This problem could not be solved within the scope of this research but should increase the effectiveness of the newly developed process. Comprehending the challenges and opportunities associated with this approach can significantly contribute to streamlining processes and enhancing efficiency. Furthermore, there is a pressing need for research to delve into effective strategies for promoting environmental consciousness among clients in construction projects. Understanding the motivations, barriers, and incentives for client engagement in sustainability initiatives can improve the development of targeted interventions and communication strategies. As this research found, improving all aspects of sustainable project management within projects should significantly increase the effectiveness of measuring sustainability at projects.

In conclusion, this study aimed to refine MKI calculation integration in Mobilis TBI's infrastructure projects, ensuring standardization and clarity. Through extensive research, two new processes were developed and aligned with the phases of a construction project. Challenges with the existing process were identified, primarily in corporate policies, emphasizing the role of contractors in sustainable measurement. Future research should focus on implementation and the validation of this research across diverse contexts. Another important aspect of future research should be the refinement of methods necessary for other categories of the SPM framework by for example improving the technical capabilities for gathering material quantities or promote client environment consciousness. Due to the interconnectedness of sustainable project management as indicated in the SPM framework, it is of high importance to address each category of this framework.

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Appendix A: Interview Guide

Introductie

1. Bedank de deelnemer voor zijn tijd en deelname.
2. Leg het doel van het onderzoek uit.
    a. Het uiteindelijke doel van dit onderzoek waaraan u vandaag meewerkt is het ontwikkelen van een nieuw proces dat de berekening van de MKI integreert in de huidig bestaande processen van Mobilis. Dit nieuwe proces moet gestandaardiseerd, controleerbaar en duidelijk worden. Om dit voor elkaar te krijgen is het belangrijk eerst duidelijk te krijgen aan welke aspecten een nieuw proces moet voldoen.
    b. Tijdens dit interview ga ik vragen stellen die als doel hebben te achterhalen wat deze belangrijke aspecten zijn. Dit doe ik aan de hand van vier categorieën die van belang zijn voor het bereiken van het doel van een proces. Deze vier categorieën zijn: Structuur, Mensen, Taken en Techniek. Voordat ik vragen stel over een van deze categorieën zal ik deze verder toelichten
3. Voordat ik begin met het daadwerkelijke interview heb ik nog wat huishoudelijke mededelingen. Allereerst, uw functie en bevindingen worden uitsluitend gebruikt voor dit onderzoek. Het interview wordt als vertrouwelijk behandeld.
4. Graag zou ik u willen vragen of het mogelijk is om dit interview op te nemen. De opname zal gebruikt worden voor het vereenvoudigen van de uitwerking van dit interview.

Introductie Vragen

1. Bij welke projecten bent u betrokken geweest die MKI als project onderdeel hadden?
2. Bij deze projecten, bij welke projectfases was u betrokken binnen dit project? (Tender/ Ontwerp/Realisatie)

Voor een proces is het van belang dat alle aspecten van de vier eerder benoemde categorieën leiden tot een hoger doel. In dat geval is het proces zo efficiënt mogelijk om dit doel te bereiken.

3. Voor de projecten waarbij u was betrokken, wat was het doel m.b.t. de MKI voor dit/deze projecten?

Vragen over de uit te Voeren Taken

Dit verwijst naar de specifieke activiteiten en verantwoordelijkheden die moeten worden uitgevoerd om het project of de organisatiedoelstellingen te bereiken. Dit omvat de taken die worden uitgevoerd door individuele medewerkers en teams.

4. Binnen het benoemde MKI-project, welke taken moesten er uitgevoerd worden om het doel te behalen?
    a. Welk van deze taken heeft u zelf uitgevoerd binnen dit project?
5. Wat waren de belangrijkste uitdagingen om deze taken succesvol uit te voeren?
    a. Kunt u een voorbeeld noemen?
6. Wat zouden mogelijke verbeteringen kunnen zijn om de taken efficiënter uit te voeren?
    a. Wat zouden taken zijn die u zelf zou kunnen uitvoeren om efficiënter richting het doel te komen?

Vragen over de Structuur

Dit verwijst naar de organisatiestructuur, de hiërarchie, de verdeling van verantwoordelijkheden en de communicatielijnen binnen een organisatie of project. Het omvat ook de manier waarop teams zijn samengesteld en hoe besluitvorming plaatsvindt.

7. Wat was de projectstructuur binnen dit project m.b.t. de MKI in de verschillende projecten/projectfases?
8. Wat waren uitdagingen in dit project door de structuur op deze manier in te richten?
9. Wat zouden mogelijke verbeteringen zijn om de structuur van het project m.b.t. de MKI te kunnen verbeteren?

Vragen over Betrokken Mensen

Dit verwijst naar de mensen die betrokken zijn bij het project of de organisatie, inclusief hun vaardigheden, kennis, ervaring en betrokkenheid. Het omvat ook aspecten zoals communicatie, samenwerking en leiderschap binnen het team.

10. Wat zijn belangrijke aspecten en vaardigheden van projectleden die benodigd zijn gedurende projecten die een MKI-aspect bevatten?
11. Wat zijn uitdagingen om projectleden met deze vaardigheden in het projectteam te krijgen zodat alle projectleden werken naar hetzelfde doel m.b.t. de MKI?
12. Hoe kan ervoor gezorgd worden dat de projectleden deze vaardigheden bezitten om het proces te verbeteren?

Vragen over de Gebruikte Techniek

Technologie verwijst naar de tools, systemen, software en andere technologische middelen die worden gebruikt in het project of de organisatie. Dit omvat zowel de hardware als de software die worden ingezet om taken uit te voeren, gegevens te verzamelen, te analyseren en te delen, en om efficiënte communicatie en samenwerking te faciliteren.

13. Welke technologie en software wordt momenteel gebruikt voor de MKI-berekening?
14. Wat zijn de uitdagingen als het gaat om het gebruiken van deze technologie en software?
15. Hoe kan de technologie en software beter gebruikt worden, of het gebruik van andere technologie of software om de MKI beter te kunnen berekenen?

Afsluitende Vragen

16. Gebaseerd op jouw ervaring, wat zijn de belangrijkste verbeterpunten voor een nieuw MKI-proces?
17. Zijn er nog andere dingen of aspecten die niet besproken zijn maar wel van belang zijn voor mijn onderzoek?

Afsluiting

1. Bedank de medewerker voor zijn tijd en deelname.
2. Verzeker de vertrouwelijkheid van het interview.

Appendix B: Focus Group Guide 1

Focus Group Guide: Evaluating and Reflecting on Identified Key Aspects and Problems.

Objective: The primary objective of this discussion is to facilitate a comprehensive evaluation and thoughtful reflection upon the key aspects and problems that have been identified during the diagnosis phase. Through this process, the aim is to gather valuable feedback that will contribute to enhancing these fundamental elements which are necessary for the development of the new process.

Duration: ca. 90 minutes

Welcome and Introduction (5 minutes)

1. Welcome the participants.
2. Give a brief overview of what will be discussed during the discussion group.
3. Explain the purpose of the discussion group.
4. A brief participant introduction.

Overview of Research and Progress (10 minutes)

A brief progress recap will be given to the participants including research goals, objectives, methods and achieved milestones. This context will help participants connect their input to the project's goals.

Explanation of Focus Group Activities (5 Minutes)

Explain to the participants of the Focus Group what they can expect from the discussion points and what is expected from them. This explanation of the Focus Group includes an example of a topic.

Feedback on Identified Aspects and Problems for the Goals (15 minutes)

First a short elaboration will be given to the participants on the identified aspects and problems concerning the goals of calculating the MKI. The identified aspects are:

1. Creating environmentally friendly projects
2. Environmental goals from the client.

An open discussion will be facilitated where the participants can exchange ideas and perspectives on the aspects and problems. Participants are encouraged to build upon each other's comments and engage in constructive discussions. The following questions are examples of questions which might be used to start the discussion:

a. What are your initial impressions of the identified aspects or problems?
b. Does anyone recognize these aspects or problems?
c. Are there any aspects or problems missing?

Group Discussion on the Aspects and Problems Identified for the Tasks (50 minutes)

First a short elaboration will be given to the participants on the identified aspects and problems concerning the goals of calculating the MKI. The identified aspects are:

1. Defining the scope
2. Making design decisions
3. Collecting quantities
4. Controlling quantities
5. Conducting and gathering life cycle analysis
6. Calculating the MKI-value
7. Verifying the MKI-value and reporting on progress
8. Contractual changes

An open discussion will be facilitated where the participants can exchange ideas and perspectives on the aspects and problems. Participants are encouraged to build upon each other's comments and engage in constructive discussions. The following questions are examples of questions which might be used to start the discussion:

a. What are your initial impressions of the identified aspects or problems?
b. Does anyone recognize these aspects or problems?
c. Are there any aspects or problems missing?

Wrap-up and Closing (5 minutes)

1. Summarize the key takeaways from the discussion.
2. Thank the participants for their valuable contributions.

Appendix C: Focus Group Guide 2

Focus Group Guide: Reflecting on Identified problems and the Definition of Design Principles.

Objective: The primary objective of this second focus group is to facilitate a discussion in which the identified problems from the first focus group are translated into design principles. A first set-up for the design principles is prepared and will be improved upon using the expertise of the experts. These design principles are a fundamental element necessary for the development of the new MKI process.

Duration: ca. 90 minutes

Welcome and Introduction (5 minutes)

1. Welcome the participants.
2. Give a brief overview of what will be discussed during the second focus group.
3. Explain the purpose of this second focus group.

Overview of Research and Progress (15 minutes)

A brief progress recap will be given to the participants including research goals, objectives, methods and achieved milestones. This context will help participants connect their input to the project's goals. Furthermore, the problems diagnosed during the first focus group will be revisited shortly.

Explanation of Focus Group Activities (5 Minutes)

Explain to the participants of the focus group what they can expect from the discussion phase of the focus group and what is expected from them. This explanation of the focus group includes an explanation of the structure used for the design principles and how the design principles will be prioritized using the MoSCoW method to assign importance of each of the design principles.

Feedback on Created Design Requirements (60 minutes)

For each of the identified problems in the first focus group a design principle has been created following the structure of Chandra (2015), during the discussion the experts are asked to make sure that these design principles are accurate with the project goals and to improve them were possible. This is done using an open discussion where participants can exchange ideas and perspectives on the problems and how these should be implemented into the design using the design principles. Participants are encouraged to build upon each other's comments and engage in constructive discussions. A white board wall will be used to prioritize the design principles using the MoSCoW method. The following questions are examples of questions which might be used to start the discussion:

d. What are your initial impressions of the design principle?
e. Would fulfilling this design principle solve the identified problem?
f. Are there any design principles missing?
g. How important is fulfilling this design principle?

Wrap-up and Closing (5 minutes)

1. Summarize the key takeaways from the discussion.
2. Thank the participants for their valuable contributions.

Appendix D: Focus Group Guide 3

Focus Group Guide: Demonstration and Evaluation of the Designed Concept MKI Process.

Objective: Facilitate a comprehensive exploration and assessment of the concept MKI process. This involves demonstrating the process to the expert group and obtaining their insights and evaluations regarding its functionality, effectiveness, and potential improvements. The objective is to gather valuable feedback that contributes to a thorough understanding of user experiences and aids in refining the MKI process.

Duration: ca. 90 minutes

Welcome and Introduction (5 minutes)

1. Welcome the participants.
2. Give a brief overview of what will be discussed during the second focus group.
3. Explain the purpose of this second focus group.

Overview of Research and Progress (5 minutes)

A brief progress recap will be given to the participants including research goals, objectives, methods and achieved milestones. This context will help participants connect their input to the project's goals. Furthermore, the created design principles during the second focus group will be revisited shortly.

Explanation of Focus Group Activities (5 Minutes)

Explain to the participants of the focus group what they can expect from the discussion phase of the focus group and what is expected from them. The activities for this third focus group include demonstrating how the new process works and discussing the possible improvements and evaluating how well the newly designed process solves the identified problems of the original process.

Demonstration of the New MKI Process (60 Minutes)

The artifact will be clarified through a live demonstration of the MKI process, detailing its key features, components, and functionalities. Throughout this demonstration, participants are encouraged to pose questions and engage in discussions, encouraging an interactive exploration of various aspects of the MKI Process. During the demonstration the identified problems and design principles where the process components are derived from will be shown as well.

Evaluation of the New MKI Process (10 Minutes)

During the assessment of the MKI process, participants in the focus group will be provided with a questionnaire. This questionnaire seeks their input on the effectiveness of the process in addressing the previously identified problems. The evaluation will be done using a Likert scale for four criteria, namely operationality, efficiency, generality and ease of use.

Wrap-up and Closing (5 minutes)

1. Summarize the key takeaways from the discussion.
2. Thank the participants for their valuable contributions.

Appendix E: Elaborated Research Findings Diagnosis Stage

Corporate Policies & Practices

In this Section, the findings regarding 'Corporate Policies and Practices' will be elaborated upon. First, the focus will be on 'Project Sustainable Value', which elaborates on the goals and strategy for calculating the MKI value. Following this, 'Project Sustainable Management Practices' will shed light on the tasks and rules required to translate the strategy into tangible MKI values. Lastly, 'Resource Value' will explore the intricacies surrounding the valuation of specific resources within Mobilis TBI.

Project Sustainable Value

Improve Environment & Company Goals

Through the conducted interviews, it became clear that the MKI calculation serves a pivotal role in monitoring and mitigating the environmental impact of construction projects (Interview 4, 6, 8, 9, 14) (Problem 8). Sustainability is an important value at Mobilis TBI by placing an emphasis on sustainable material choices, environmentally friendly transportation practices and construction methods (Focus Group 1). All of this is geared towards creating cleaner and more environmentally friendly construction projects (Interview 7) (Problem 8). Notably, Mobilis is exploring the possibility of implementing MKI assessments across all their projects, not exclusively those where the client mandates the calculation of the MKI value (Interview 3). Mobilis wants to calculate the MKI for all their projects. This is done to have a comparison between Mobilis projects concerning the environmental impact of the projects (Interview 3) (Problem 8). However, for this approach to be effective it is mentioned that the company must set clear goals for the project teams. Otherwise, it is extra work for the project team without a goal and they could use that time and effort for other activities during the project (Interview 10, 13). The experts participating at the focus group identified that the question on how Mobilis is going to make sure their projects are environmentally friendly is a relevant issue to consider once this process is standardized within the company (Focus Group 1) (Problem 8).

Stakeholder Goals

Nevertheless, in many cases, the requirement to calculate MKI arises from the client, often incentivized by the prospect of gaining a competitive edge during the procurement process, as outlined in Section 2.2 (Problem 1). Achieving certain MKI value targets carries substantial significance as it can create a tangible advantage during the procurement. During the procurement phase, securing the optimal balance between cost and quality remains a paramount criterion for contractor selection. Nowadays, many clients factor MKI considerations into their evaluation of the economically most advantageous tender (EMVI) criteria, where meeting MKI thresholds can give distinct benefits within the procurement contract (Problem 9). However, this advantage could pose a risk. During the tender phase, assumptions are made, and sometimes, upon closer examination, these assumptions may prove unfeasible. This phenomenon will be further elaborated in Section 'Uncertainty'.

An additional point mentioned by the experts from the focus group, is that the MKI has never been decisive in a design decision. For these projects to become more environmentally friendly it was suggested that it should be given more weight by the client. Currently, price dominates in the trade-off matrix when making design decisions (Focus Group 1) (Problem 9).

Project Sustainable Management Practices

Defining the Scope

A pivotal task in SPM is the thorough exploration and definition of a projects scope. This task is crucial for the new process because decisions about what to include or exclude from the scope have significant consequences on the ultimate MKI-value (Document 1, 3; Interview 3) (Problem 1). However, this task is far from straightforward due to the variability in MKI scope across different projects, as clients shape the scope for each specific project (Problem 10). Given this variability, meticulous consideration is necessary to establish the precise boundaries of what falls within the projects scope (Problem 1). The project scope cannot be blindly adopted from a previous project (Focus Group 1) (Problem 1). Examples of this variability include the exclusion of materials like road furniture and groundwork or the tracking of transport distances and working hours of personnel (Interview 1, 4, 5) (Problem 10).

The process of determining the scope relevant to a specific project primarily involves contract analysis and weighting linked to MKI (Interview 11). Furthermore, the calculation methods may change over time and should be carefully considered during the contract analysis (Problem 7). This is because projects may have varying reference dates that directly impact the calculation method used at the time the project was initiated (Interview 11)

However, the task of defining the scope does not conclude with the initiation phase. In the planning and execution phases, the project team must remain updated when new team members are involved, ensuring clarity about what is included in the scope and what is not (Interview 8, 13) (Problem 1). The focus group experts diagnosed that when there is no project focused strategy, problems could arise (Focus Group 1).

Making Design Decisions

Plenty of different choices and decisions need to be made during construction projects that shape the project. During the initiating, planning, and executing phases of a project, there will be decisions that will have a significant impact on the projects MKI value, and these must be evaluated during the project. As a result, this consideration is critical for the development of the new MKI process (Interview 2, 7; Document 3, 4).

A growing body of research has emphasized the importance of assessing environmental impact early in the project life cycle (Meex et al., 2018; Naneva et al., 2020; Scherz et al., 2022). Traditionally, project decisions primarily revolve around cost and schedule considerations, with sustainability factors receiving less attention. However, studies, such as Cavalliere et al. (2019), have mentioned the need for a more comprehensive approach that considers environmental and cost implications from the projects inception. By doing so, project teams can identify opportunities for sustainable choices that align with MKI goals and prevent costly retrofitting or modifications later in the project.

In practice, it has been observed, both through interviews and project documentation, that the MKI is increasingly being incorporated into trade-off matrices (Interview 4, 7, 15). This strategic inclusion allows decision makers to compare project alternatives based on a broader set of criteria, including sustainability. The integration of MKI values into these matrices enables a more balanced evaluation of options (Interview 12, 14).

To ensure the consistent and effective application of MKI considerations in the decision-making process, it is important to standardize these practices within the construction industry. The inclusion of the MKI in trade-off matrices has already been standardized, however it is not standard practice to execute this part of the trade-off matrix during projects. The experts from the focus group noted that the cause for this could be a lack of knowledge and awareness on who is responsible for this task (Focus Group 1) (Problem 6). Therefore, clear roles and responsibilities must be established to define who within the project team is responsible for assessing the MKI values of design solutions (Problem 3). Furthermore, it was found that interviewees noted that it would be desirable to implement the MKI in all trade-off matrices in the future MKI process (Interview 4, 7, 15). Also, possible implementation of BIM in the future could make it insightful what impact a certain choice or decision would make (Interview 6).

Collecting Quantities

Conducting a Life Cycle Assessment, such as the MKI investigated in this research, is an intricate and multifaceted task. An important component within the to be created process for Mobilis TBI, as also underlined by prior studies by Meex et al. (2018) and Najjar et al (2017), is the collection of material quantities. The practice of quantity collection could also be seen in Document 1, demonstrating its significance in the MKI calculation process at Mobilis TBI. During the conducted interviews, several key findings emerged regarding the incorporation of material quantity collection for the to be design MKI process at Mobilis TBI.

First, it was identified that three primary functions play critical roles in the collection of quantities, namely, work preparation, model designers, and calculators. Each of these functions have distinct advantages and disadvantages in the execution of this task (Interview 1, 2, 3, 4, 5, 6, 8, 9, 13 & 15) (Problem 3).

The first function, often involved in material quantification, is the role of modeler. These individuals have intricate knowledge of the projects design and manage detailed 3D Models of the project (Interview 3, 6). These models give the modelers the ability to streamline the process of quantity extraction by providing accuracy and reducing manual effort. Notably, projects such as Vierpaardjes have adopted 3D modeling to collect quantities, with modelers incorporating labels to components to facilitate easy quantity extraction (Interview 4, 5). However, it is worth noting that in 3D models in current projects at Mobilis TBI, instances exist where the decision has been made to leave out certain project components caused by time constraints of the modeler (Problem 10; 11). An example of this was given by Interviewee 15 who stated that for a certain project where cinderblocks were part of the scope for the MKI calculation. However, these were not added to the 3D model and had to be added manually to the material quantification (Interview 15).

The second function, calculators, are experts in determining quantities for all project materials, ensuring accurate price determination. Their meticulous evaluation of the project's financial aspects is indispensable. Nonetheless, there are some disadvantages associated with their role during material quantification. The major drawback is the time constraints experienced by calculators in the final weeks before a major deliverable (Interview 15) and the lack of calculators within the company in general (Interview 1).

The final function involved in material quantification is work preparation. These teams serve as the backbone of project logistics, boasting a profound understanding of project management intricacies. Their expertise in anticipating on-site requirements ensures that essential resources are available when needed. However, despite their logistical proficiency, work preparation teams may occasionally lack a comprehensive understanding of the projects design intricacies (Interview 8, 9).

Collectively, design, work preparation, and calculator teams work together in material quantity determination, particularly concerning the technical aspects of MKI calculations. The allocation of this task varies from project to project, often involving a combination of these three functions, with roles shifting as different project phases unfold. Designers are more prominent during the initiation phase, while work preparation takes over during the planning phase, often with a controlling function for calculators (Problem 4). In the execution phase, the work preparation team typically has access to the quantities of materials used during the project (Interview 13, 2, 6; Document 3, 4) (Problem 3).

Ultimately, the responsibility for quantity collection is determined for each project separately based on the scope of the project and the availability of personnel for that specific project (Problem 1; 10). Even though the selection of the role conducting this task is made with careful consideration to ensure accurate and efficient quantity assessments, the lack of a standard responsibility to conduct this task causes unclarity (Problem 3). Therefore, it has been indicated during the interviews and the focus group that the roles and responsibility for the collection of material quantities should be standardized and integrated to minimize the manual labor that must be conducted (Interview 1; Focus Group 1) (Problem 3; 11).

Controlling Quantities

An important aspect of the new MKI process is ensuring the accuracy and coherence of material quantities at the end of a design phase (Problem 4). This task entails two critical components: first, ensuring that the quantities specified in various sections of the design align with one another. As an example, ensure that the quantities used in environmental impact assessments correspond to those used in cost estimations (Interview 1). Second, it entails confirming that the MKI quantities accurately reflect the scope of the project (Interview 8) (Problem 4).

According to the interviews, discrepancies in quantities between calculations or project scope can lead to errors, affecting not only environmental impact assessments but also possibly cost projections (Interview 3) (Problem 4). Especially during the end of the tender process when decisions are required to be made quickly, it could occur that calculations are made with two different material quantities (Focus Group 1) (Problem 4). To avoid this, it was suggested that input validation and quality checks should be performed collaboratively between work preparation and project management teams (Interview 10). This method would aid in ensuring that all quantities are accurately represented, and that scope coverage is complete (Problem 1). Furthermore, it was suggested that these quantity verifications should be incorporated into the workflow to ensure that quantity discrepancies do not occur due to the pressure of project deadlines (Interview 8) (Problem 4).

Conducting and Gathering Life Cycle Analysis

The Section 'Making Design Decisions' explored the significance of informed decision making in the design process, which is facilitated by trade-off matrices, and highlighted the importance of the MKI value in considering the environmental impact of these decisions. As detailed in Section 2.2, MKI values are derived from Life Cycle Assessment calculations by considering 19 impact categories which quantify the environmental impact of a specific material. Typically, for most materials market average MKI values are stored in the NMD. However, these values are conservative since a buffer is added to ensure that the market average values do not underestimate the true environmental impact when specific materials have not been tested (Interview 3, 8) (Problem 2).

To optimize MKI values for specific projects or design choices, relying only on generic data is insufficient. This is where product specific LCA's are being used (Document 2). These LCA's are tailored to the precise specifications of a particular product or material, ensuring the most accurate and up-to-date information is available for the trade-off matrix. Using product specific LCA's allows for a more accurate assessment of environmental impact, often yielding values lower than generic database averages. In many cases, sustainability coordinators or external LCA experts, mostly in large projects, are entrusted with this responsibility (Document 5; Interview 1, 12) (Problem 3; 7).

Choosing which products and materials should be considered for conducting product specific LCA's involves considering multiple factors. Firstly, the potential environmental impact of an item is a crucial consideration. Items that have significant influence on the overall project MKI value should be prioritized. Moreover, Items crucial to meeting sustainability goals or adhering to regulatory requirements may also justify this level of analysis (Document 4). For many project members it has been unclear which materials should receive a specific LCA and where these can be gathered, even though this information is available at the sustainability coordinator (Focus Group 1) (Problem 7).

Furthermore, it is essential to recognize that LCA values are not static. They can change over time due to changing criteria, calculation methodologies, technologies, or evolving products. Consequently, LCA values should be reevaluated for each project. Given the time and effort involved in this process, careful consideration should be given to selecting which product specific LCA's are conducted (Interview 3, 10) (Problem 7).

Calculating the MKI-value

The next crucial step in developing the new MKI process involves calculating the MKI value itself. As explained in Section 2.2, this calculation is performed by multiplying the quantities of all materials by their respective environmental impact factors.

It is important that the individual responsible for this calculation possesses the necessary knowledge and training (Interview 4) (Problem 3; 6). While the actual calculation may not be overly complex, experience with it holds significant importance (Interview 13) (Problem 6). However, it remains unclear from the interview findings who should have the responsibility for performing the MKI calculation (Problem 3). Some suggest that a modeler or a planning engineer should take charge, while others argue that a specialist, such as a sustainability coordinator, should handle this task. This unclarity is an important issue to consider with the creation of the new process (Focus Group 1) (Problem 3).

Nevertheless, there is a discussion surrounding the potential for automating MKI calculations. If software tools like Revit can efficiently extract quantities and link them to appropriate MKI values, it may become feasible for modelers to handle these calculations automatically (Interview 6)

Verifying the MKI-value and Reporting on Progress

At Mobilis TBI, the verification of the MKI budget for their projects is a major part of the process aimed at ensuring compliance with environmental objectives. This task involves several key findings as outlined by various documentation and interview sources (Document 1, 3, 4, 5; Interview 1). The verification of the MKI-budget is based on the careful analysis of the scope described in the Section 'Defining the scope' since a verification must ensure that all requirements from the client are verified (Interview 2, 3, 12) (Problem 1). The first aspect that needs to be verified are the management requirements. This involves adhering to various management standards and specifications. To verify this, a management plan is used to outline how the project will fulfill these requirements and provides a concrete roadmap for implementation (Interview 12).

Another part is the verification of the MKI-value itself. This is not a one-time consideration but after the project has been awarded ongoing management is essential. It includes monitoring and ensuring that the project remains on track to fulfill the MKI promises made during the tender phase. This includes delivering the specified quantities and adhering to MKI budget constraints (Interview 8). Throughout the project, project teams must continuously assess design choices in terms of their impact on MKI and budget. Questions arise regarding the feasibility of design modifications, such as using thicker floors and thinner walls. These choices can have repercussions on both the MKI and overall budget (Interview 3).

When it comes to verifying and monitoring MKI progress, a pivotal aspect involves providing regular reports detailing the achieved progress in terms of MKI values (Document 1, 2; Interview 3, 8, 10). These progress reports serve the vital purpose of keeping stakeholders updated on the current MKI status, and they also contribute to the assessment of potential penalties for failing to meet MKI targets.

At the conclusion of each design phase and periodically in accordance with client requirements, comprehensive progress reports are generated to document the ongoing advancements. These reports carry substantial significance, as they are not only contractually mandated but also serve as a fundamental tool for transparent communication (Interview 1). Currently it varies who is responsible for reporting on the progress of the MKI-value (Problem 3). However, most have suggested that the sustainability coordinator should be responsible for this task instead of the project team, ensuring a standardized and consistent approach to reporting (Interview 1, 10, 12). Establishing such a standardized method for MKI calculation and reporting has been recognized for maintaining consistency and facilitating efficient monitoring. This endeavor would involve establishing clear guidelines and agreements for the structure of these reports.

Contractual Changes

When tendering a project, strict compliance with a set MKI value is mandatory. Failure to comply with this requirement may result in financial penalties, as mentioned in Section 2.2. However, a circumstance may arise where contractual change may be necessary and because of this the set MKI-value needs modification as well (Document 5) (Problem 5). Because of this, in situations where a request for contract alteration is initiated, it becomes important to conduct a thorough assessment of the potential implications for the MKI-value (Document 2; Interview 3). It is important to look carefully at what changes are being made to the contract and how these should be included in the project (Interview 8, 13). Currently this task is not always conducted, however it is identified that always conducting this analysis is a key aspect of the new process (Focus Group 1) (Problem 5).

Resource Value

Advice from the Sustainability Coordinator

The sustainability coordinator currently is tasked with the responsibility of various operational tasks, including making sure quantities are collected, the extraction with LCA values from suppliers, and performing MKI value calculations. However, this workload is proving challenging for one person across numerous projects (Interview 10). Therefore, it is essential to reconsider the responsibilities of the sustainability coordinator and find a more effective way to manage these tasks in the new process.

Within the MKI-process there are certain crucial responsibilities which should always be executed by the sustainability coordinator (Problem 3). One of these responsibilities is the coordinators' role to have an advisory position in the project team regarding to the environmental impact of the project and ensure the acquisition of the best possible LCA values for MKI calculations (Interview 1, 4, 5, 10, 15) (Problem 7). While the sustainability coordinator currently handles many operational tasks, their effectiveness would improve if they could allocate more time to providing guidance (Interview 4). Their advice should offer practical insights and market awareness, such as knowledge of new eco-friendly materials or suppliers (Interview 3). They should also assist in understanding the LCA values within the DuboCalc system and identifying the most effective adjustments (Interview 5, 10) (Problem 7). This advice can only be given when administrative work such as collecting quantities and making the MKI calculation can be delegated to the project team itself when standardized and simplified.

Resource Management

In this Section, the findings regarding Resource Management will be elaborated upon. This elaboration includes how resources, which encompass capital, material, and human resources, can be allocated efficiently. When viewed from the perspective of project portfolios, leveraging advanced technologies and techniques for monitoring resource allocation empowers organizations to attain a significant competitive edge.

Time and Labor

One aspect that each of the tasks, elaborated in Section 'Project Sustainable Management Practices' have in common is that they cost time and labor to be completed (Interview 1, 4). Since the main goal is to build the project instead of calculating the MKI it should cost as little time as possible (Meex et al., 2018; Scherz et al., 2022). As certain tasks often extend beyond the preferred timeframes, a recurring issue arises where the quality of task execution is compromised (Focus Group 1) (Problem 4). Therefore, it would be advantageous to limit the time and labor needed to invest to conduct all the mentioned tasks by standardizing and automating the tasks and taking informed decisions on who has sufficient amount of time to conduct the tasks, which will be elaborated upon later in this Section (Interview 12, 15).

Responsibility & Expectations

One significant challenge in large-scale projects is ensuring a well-defined allocation of responsibilities and tasks for each of the elaborated tasks (Interview 3; Focus Group 1) (Problem 3). While the overall responsibility for the MKI process lies with the tender or project manager overseeing the entire project, clarity has been lacking regarding the specific responsibilities within each sub-process of the MKI (Interview 1, 2, 5). Through the conducted interviews it became apparent that Mobilis TBI employees hold differing views on the responsibilities and task division for the new process, mostly on the responsibility of conducting the actual MKI calculation and collection of material quantities, which could be seen in Section 'Project Sustainable Management Practices' (Problem 3). For the new MKI process to be effective, it is crucial that the responsibilities and expectations for various tasks within the MKI process are clearly defined (Interview 2, 3) (Problem 3).

Dubocalc

To determine the MKI value of a project various tools and software are used (Document 1, 5; Interview 1, 2, 3, 6, 7, 8, 15). The most important tool is DuboCalc as it is used to calculate the actual MKI value by giving the tool the input of the collected quantities, which is described in Section 'Collecting Quantities', multiplied with the environmental impact per unit for each of the materials. In the acquired data some interesting findings have been found. It is mentioned that not all personnel have access to DuboCalc since there is a limited number of licenses and not everyone understands how to use the tool (Interview 2, 5). Since these two findings are the case, it is recommended that the sustainability coordinator is responsible for making the calculations using DuboCalc.

The final finding is that it is recommended to explore automating the calculation to make the process more efficient and less reliable on manual input by creating a data exchange between BIM and DuboCalc (Interview 3, 6). This finding will be further explored in Section 'Automation & Coupling'.

Excel

Another essential tool for managing MKI-related data and calculating MKI values is Microsoft Excel (Document 2). Project progress regarding MKI values, both the proposed and actual executed values, are documented using Excel files and added to the progress reports, which have been described in Section 'Verifying the MKI-value and reporting on progress'. These Excel spreadsheets replicate the

DuboCalc calculations and include optimized LCA values from the task outlined in Section 'Conducting and Gathering Life Cycle Analysis' (Document 3).

Additionally, the findings place a strong emphasis on collecting quantities from a 3D model and exporting these into an Excel spreadsheet (Interview 6). This tool will be further elaborated in Section 'BIM. Further findings include that Excel offers great usability throughout the company since it is a widely known and used tool and can also facilitate file sharing. However, there are concerns about potential errors stemming from manual input. Therefore, the importance of implementing verification mechanisms is mentioned (Interview 8) (Problem 11).

Despite these concerns, Excel remains the preferred tool for tracking quantities and performing MKI calculations, which can be converted into DuboCalc calculations for client purposes by the sustainability coordinator (Interview 10, 12, 13).

BIM

The final major tool that is used in the current process for determining the MKI value at Mobilis TBI is Revit, which is a type of BIM tool. Currently BIM is used for creating a 3D model of the design to make sure creating drawings for the building is easier than when it would have been done using for example old computer drawing tools such as AutoCAD (Interview 3). In relation to the MKI process an important use for the 3D model in BIM is the extraction of material quantities from the 3D model for the collection of quantities described in Section 'Collecting of quantities' (Interview 1, 6, 4, 5, 8, 12) (Problem 11).

For the future there is a desire to integrate MKI values into BIM models, which is a research direction that is widely researched (Jalaei & Jrade, 2014; Naneva et al., 2020). The most important research regarding this research direction has been described in Section 2.4. The goal is to streamline MKI calculations and potentially automate the process within software such as Revit, a BIM tool (Interview 6, 15). While the desire is there to integrate the MKI value calculations in BIM, the challenges related to the complexity and the dynamic nature of construction materials currently prevent this full integration (Interview 8). It is noted that the first step is to standardize the process for the calculation of the calculation of the MKI value, after which further research could streamline this process by automating the calculation using BIM (Interview 6). Important for this streamlining is the consideration of metadata assigned to 3D model elements to make sure that the right data is readily available for the calculations. For future integration of these tools, it would be useful for the new process to consider this metadata (Interview 6, 8).

Standardization

As previously mentioned, Mobilis aims to calculate the MKI for all its projects as a standard practice. To enable effective project comparisons and minimize the effort required for MKI calculations, it is essential to standardize the process (Interview 1). A standardized process also simplifies auditing procedures (Interview 2, 3).

Currently, at Mobilis, MKI calculations are not ingrained in the standard workflow, resulting in a learning curve and unfamiliarity among project personnel (Problem 6). Standardizing the process would make it easier for project team members to work with MKI during a project (Interview 12).

Automation & Coupling

The acquired data from the interviews highlights the significance of automating MKI calculations to eliminate manual parameter input and reduce the potential for human errors (Interview 4, 6, 12, 15). Currently, much of the process relies on Excel and manual input, but there is a strong desire to create a more seamless connection between the described software tools BIM, DuboCalc, and Excel

(Interview 1, 8). However, it is acknowledged that the potential for automating data exchange would need further exploration within the company (Interview 6) (Problem 11).

The eventual objective is to enhance the efficiency of data management, particularly regarding the collection of quantities (Interview 2). The aspiration is that modelers can effortlessly generate MKI values based on materials and quantities within their designs, without the burden of manual calculations. However, achieving this automation requires substantial research into the technical aspects and integration of databases, models, and calculation tools (Interview 6). Additionally, it is crucial to ensure that the generated MKI values are project specific and accurate. Currently, there is not yet the possibility of automating the calculation of the MKI and coupling the different ITC tools with each other. However, with the to be created process for the calculation of the MKI value the possibility for automation and coupling should be considered to lay the groundwork for future automation and coupling in construction projects of Mobilis TBI (Interview 6).

EXTENDED PROJECT LIFE CYCLE

This Section elaborates on the findings of the Extended Project Life Cycle. First, Resource Life Cycle focuses on sustainable resource management from acquisition to disposal, promoting efficient resource use and environmental responsibility. Thereafter Project's Processes Life Cycle includes all project stages, emphasizing the integration of sustainability principles from project initiation to post-project evaluation. Finally, the Subsection Effects Life Cycle involves assessing and managing the long-term social, environmental, and economic impacts of a project to maximize positive effects and minimize negative ones.

RESOURCE LIFE CYCLE

For the resource life cycle within the MKI process three critical aspects have been identified. First and foremost are the sustainability goals that Mobilis has set for itself concerning the use of environmentally friendly products (Problem 8). Currently, the company exclusively employs FSC-certified wood, but there is room for further enhancement. Consideration can be given to establishing specific MKI limits for various materials, thereby reinforcing Mobilis' commitment to environmental responsibility (Focus Group 1).

Also important is the influence Mobilis has in steering its suppliers toward more eco-conscious practices. This aspect involves ensuring that the selected materials remain consistent throughout the project's duration. It is imperative that the initially chosen environmentally friendly materials are not substituted with less sustainable alternatives. An illustrative example of this pertains to a past scenario in which a proposed grind material became unavailable, necessitating the transportation of an alternative from Scotland to the Netherlands, resulting in a considerably less eco-friendly solution. Thus, the stability of environmentally sound material choices is paramount in the resource life cycle (Focus Group 1). Above all, the resource life cycle is intrinsically linked to the project scope, detailed in Section 'Defining the Scope'.

PROJECTS' PROCESSES LIFE CYCLE

Level of Detail

In construction projects it is common to not know exactly what to build at the start of the project and the detail of the plans increase over time (Meex et al., 2018) (Document 4; Interview 10) (Problem 2). This is called level of detail and is also an important aspect in the environmental calculations of Mobilis TBI (Soust-Verdaguer et al., 2017) (Document 4, 5). The further you come in the designing process the more specific information is available. However, as described in Section 2.3 the further you come in the designing process the less impact can be achieved with the design choices at hand. Therefore, it is found that to have impact on the environmental impact of a project it is important that from the start of the project the MKI is considered, and design decisions consider the MKI as described in Section 'Making Design Decisions'. Taking into consideration what level of detail is possible while having the biggest impact on the design is an important aspect to consider in the new MKI process (Interview 6, 8).

Uncertainty

As discussed in the previous Section, at the start of the design process, the precise project details are often unclear. This introduces a considerable amount of uncertainty that needs to be factored into the MKI value of the project (Problem 2). This is because a significant portion of the values used in the initial phases are based on estimates derived from the NMD or historical data from other projects, while still willing to have a competitive offer to win the tender (Document 3; Interview 8) (Problem 2). After the initiation phase it may turn out that some of the estimates are not achievable (Focus Group 1). During the early design phases, there is also uncertainty regarding the availability of materials in stock among suppliers (Interview 7). Furthermore, there is the potential for unexpected issues to arise during project execution.

Given all these uncertainties, it is essential to adopt a strategy that assesses the level of risk acceptable for the MKI throughout the project (Interview 1) (Problem 2). To avoid falling short of the established goals and incurring penalties, it's wise to maintain a buffer beyond the contractual MKI requirement (Interview 1). For this reason, it is recommended to incorporate a bandwidth into the project to mitigate these risks instead of cutting this bandwidth during tenders to have a more competitive offer (Focus Group 1) (Problem 2). As the project progresses and uncertainties decrease in each phase, this bandwidth can be gradually lowered (Interview 4, 9) (Problem 2).

Responsibility Intricacies throughout the Project Phases

In Section 'Project Sustainable Management Practices', encompassing an overview of the to be conducted tasks, it becomes evident that many of these tasks entail evolving responsibilities as the project transitions through its various phases (Problem 3). To illustrate, consider the task of collecting material quantities. During the initiation phase, designers take the lead, while the planning phase witnesses the transition of responsibilities to work preparation, often accompanied by a supervisory role for calculators. As the project advances into the execution phase, it is typically the work preparation team that gains access to the detailed quantities of materials employed throughout the project (Interview 2, 6, 13, Document 3, 4).

EFFECTS LIFE CYCLE

The effects life cycle relates to the assessment and management of the long-term impacts and consequences of a project. It involves evaluating the social, environmental, and economic effects of the project, both during and after its completion. SPM aims to minimize negative effects while maximizing positive impacts. This life cycle ensures that projects contribute to the well-being of society and the preservation of the environment over the long term.

However, it is worth noting that the determination of a projects scope is primarily at the discretion of the client. Consequently, the MKI process examined in this research does not directly influence the Effects Life Cycle. As such, the Effects Life Cycle falls outside the specific scope of this research.

Stakeholders Engagement

The Section on stakeholder engagement provides an elaboration of the critical aspects related to this dimension. This Section emphasizes the significance of effective communication for stakeholder engagement in achieving project success and aligning sustainability objectives. This includes both the project team as the client.

Communication Structure within Project Team

Effective team communication plays a pivotal role in project success, particularly during the initiating phase when project plans are susceptible to change (Scherz et al., 2022). Maintaining open lines of communication is crucial. It is essential for the project team member responsible for collecting material quantities or making the MKI calculation to grasp intricacies of these tasks, also specific to the scope of that particular project, and collaborate closely with the sustainability coordinator (Interview 3, 4, 7, 8, 15) (Problem 1).

To ensure that the project teams' knowledge regarding the environmental impact remains current, periodic meetings are essential (Interview 3, 14) (Problem 6). The period between these meetings can vary since for some projects or project phases discussing the environmental impact of the project is more important than during other projects or phases. These sessions could provide a platform to discuss collective experiences, share insights gained from suppliers and industry developments and progress of the project's environmental impact calculations (Interview 14). In case where effective communication between the project team members breaks down, as exemplified by a situation in one of Mobilis projects where data was not delivered to the sustainability coordinator, it could cause that the environmental impact goals of the specific project may not be achieved (Interview 1).

Another significant challenge pertains to data handling, of which the interviews showed that this should be standardized (Interview 2). Frequently, documents are sent to people within the company containing fragmented information in a non-standardized manner. This lack of organization could lead to wrong inputs or inaccurate outputs of the MKI calculations as well as increase the time necessary to complete all the tasks because of the low efficiency.

An especially crucial moment in the communication structure is the moment a new team member joins the project team, or when a team member leaves the project team. An example of such situation is when the initiating phase is finished, and the project goes into the planning phase. Concerning the communication structure, it is of importance that these new project members, or the project members taking over certain tasks and responsibilities are up to date about the MKI in the project (Interview 3, 8, 10, 12) (Problem 3).

Communication Skills

For projects, having effective communication skills is essential. Teamwork results in better outcomes if communication is efficient (Interview 13). Additionally, it's critical to keep one another informed and record information in a matrix or checklist so that everyone is aware of what must be done during other projects (Interview 14).

Communication skills are also important because through the sustainability coordinator there is a direct line too designers, suppliers, or producers. Everyone involved in the process, regardless of their role, should be aware of what will happen. In addition, when someone need certain information, it is important to be able to find the right person for that. Moreover, people should also feel like they can ask questions and they should know who they can ask these questions to (Interview 12).

Communication with the Client

Effective communication with the client is essential for successful project management. Concerning the MKI this communication has several reasons, encompassing discussions of the value of MKI in the project, navigating changes in project contracts and reporting on progress.

As detailed in Section ‘Stakeholder goals’, the MKI has not yet played a decisive role in projects. Experts from the focus group have indicated that it might be beneficial for clients to prioritize environmental objectives within their projects. Even when Mobilis is willing to embrace environmentally friendly projects, they might face constraints due to the potentially higher costs associated with such design solutions. In this context, maintaining open communication with the client becomes essential. It can involve advocating for the increased importance of these objectives within the project or engaging in discussions to explore cost-effective environmentally friendly design alternatives (Problem 9).

In projects, contractual changes may become necessary for various reasons. Adjustments to the project scope, timelines, or objectives could be initiated, potentially impacting the established MKI-value (Document 5) (Problem 1). In such situations, the clients’ requirements and expectations may evolve, necessitating a thorough assessment of the implications for the MKI-value. Effective communication with the client throughout this process is crucial to make sure that the MKI is considered correctly for the contractual change (Interview 8, 13) (Problem 9).

Another fundamental aspect of communication with the client revolves around the verification of the MKI budget. This intricate process aims to ensure that the project aligns with the client's environmental objectives (Interview 2, 3, 12). This has been elaborated further in Section ‘Verifying the MKI-value and reporting on progress’.

Organizational Learning

Organizational learning plays a critical role in enabling project teams and organizations to adapt, improve, and align with sustainability goals. This Section explores how organizational learning influences project success and highlights strategies and practices that promote a culture of continuous learning, ultimately enhancing project performance and sustainability outcomes.

Knowledge

When employees understand what an MKI-calculation means, what certain aspects entail, and how it works, then it is easier to know what to do in what situation (Interview 13) (Problem 6). The sustainability coordinator typically has substantive expertise in sustainability, whereas technical aspects, requirements, and design knowledge are embedded in the project team itself. Collaborative efforts are critical in establishing and reporting accurate MKI data, and spreading this knowledge encourages greater participation (Problem 6). When multiple people are familiar with the process, more precise calculations become achievable, highlighting the importance of easily accessible training courses on MKI (Interview 1). Currently, not everyone understands the tasks involved with calculating the MKI, which causes unnecessary difficulties with the implementation of the MKI in projects (Focus Group 1). Increased knowledge on what the MKI entails by using training courses and the development of e-learning resources could bridge this gap if people are encouraged to make use of them (Interview 1, 3; Focus Group 1) (Problem 6). Furthermore, for Mobilis to advance further in the use of the MKI, it must remain informed about sustainable alternatives and stay on top of market developments. During meetings, personnel handling specific subjects can share updates with their colleagues (Interview 7) (Problem 6).

Experience
When MKI is applied properly, understanding will eventually follow. Knowing where the mistake is made makes it easier to have an impact on the process, which also helps with making the right decisions (Interview 10). With experience, this leads to quicker decision-making. A good analogy is drawing information from a database where important information resides, enabling rapid decisions. Crucially, it is important to remember that people who work frequently with the MKI gather more experience and therefore have a greater expertise in its application (Interview 14) (Problem 6).

Nevertheless, the current situation is characterized by limited experience with MKI, except for the sustainability coordinator. There are few personnel within the organization who have worked on more than a couple of projects involving MKI, which hinders the accumulation of expertise and a deeper understanding of the MKI application. This underscores the need for initiatives to expand experience and knowledge across the organization to harness the full potential of MKI in project management (Problem 6).

Awareness
A key finding in the data collected for the new MKI process is that project team members should be aware of their impact on the MKI during the project. The goal of the awareness effort is to highlight that collective efforts are aimed at meeting sustainability criteria. The Sustainability Coordinator is responsible for laying the groundwork for demonstrating sustainability compliance, with input from various project disciplines that are directly involved in the subject (Document 4) (Problem 3).

One perceives MKI awareness as primarily the project managers responsibility (Interview 10). While it is important, it should not overshadow the project managers primary responsibility, which is to ensure the projects continuity rather than focusing solely on sustainability (Interview 1) (Problem 3). A proposed vision is to incorporate sustainability, particularly MKI, into the standard agenda, much like safety, to keep it at the forefront of everyone’s mind. This idea requires widespread acceptance, with project personnel always considering the long-term consequences of their decisions. Currently, sustainability is not always thought to be appealing because its effects are not always obvious. This could take years to manifest. As a result, it is critical to emphasize the importance of sustainability awareness right now (Interview 2). Furthermore, it is critical that all project stakeholders recognize the significance of MKI, ensuring broad participation beyond those directly involved in the project. All individuals involved in the process must consider MKI at every stage of the process (Interview 3, 6).

In essence, MKI scores must be considered at every stage of the process, with all parties involved considering their implications. Also as mentioned in this Section, employees should be trained to have the understanding needed to make decisions that go beyond cost considerations. This two-pronged approach, which combines awareness and education, keeps MKI at the forefront of project considerations (Interview 12).

Motivation
Motivation is another important identified aspect regarding the skills project members should have for the new MKI process. It is noted in the interviews that the MKI is not particularly appealing for technicians and that they are rather focused on their technical work (Interview 2). It is believed that demonstrating how adjustments can be made to the calculations to decrease the environmental impact of the project, could make technicians become more interested in the MKI (Interview 8). Holding presentations within the company about sustainability goals does not energize the average engineer. They would rather work with numbers and calculations while figuring out how to build structures like garages, viaducts, and bridges (Interview 5, 8).

Data

Previous research underscores the undeniable importance of having access to a robust database for achieving successful project outcomes (Safari & AzariJafari, 2021; Scherz et al., 2022). Unfortunately, this vital resource often proves to be lacking. Furthermore, in Section 'BIM' it was observed that the effective use of metadata associated with modeled 3D elements is essential for automation. To ensure successful automation and coupling of the different tools an efficient data structure becomes a critical factor (Interview 2).

A noteworthy example of the value of data is found in the use of specialized libraries, as demonstrated by a project that engaged with an external MKI-specialist (Problem 7). This specialist maintained a library of historical data, greatly simplifying the process of making informed decisions (Interview 5). Additionally, Interview 7 highlights the potential benefits of creating a comprehensive database founded on experiential data, particularly when considering choices related to concrete mixtures. While historical data can be a valuable source, the need for project specific LCA's is necessary. However, a notable challenge arises in terms of timing, as subcontractor involvement often occurs post the final design phase, resulting in a temporal misalignment (Interview 8) (Problem 7).

Looking ahead, the integration of 3D modeling into the decision-making process is gaining prominence. This visual approach not only aids in understanding spatial utilization but also allows for practical considerations, such as cost and sustainability. By modeling different design options and attaching cost and sustainability metrics, it becomes possible to foresee the consequences of various design choices (Interview 6).

Appendix F: Summary Focus Group 1

De focusgroep werd afgetrapt met een korte presentatie waarin het doel van het onderzoek en de uitvoering daarvan werden toegelicht. Vervolgens is er besproken hoe de focusgroep zou worden gevormd aan de hand van procesonderdelen en de daarbij horende problemen. Daarnaast werd er ook uitgelegd hoe de besproken procesonderdelen en problemen gewaardeerd zouden worden aan de hand van de waarde-inspanning matrix.

Na de introductie voor deze focusgroep werd van de inhoud als eerste het doel besproken voor de ontwikkeling van het MKI-proces. Het voornaamste doel is het verbeteren van de milieu-impact van Mobilis TBI-projecten. Uit de interviews is gebleken dat er een mogelijk gebrek is aan duidelijke interne doelstellingen met betrekking tot MKI, vooral wanneer MKI-berekeningen uitgevoerd zouden worden zonder specifieke doelstellingen van de klant. Deze aangekaarte zorg, startte een discussie over de vraag of milieu een kernwaarde moet worden binnen Mobilis, en welke rol Mobilis hierin wil gaan spelen binnen haar projecten en hoe je die geuite doelstellingen gaat borgen.

Het tweede doel is dat de MKI-berekeningen vaak worden uitgevoerd aangezien de klant om deze berekening vraagt in hun contract en daarmee duurzamere projecten een competitief voordeel kunnen bieden. Bij dit doel werden ook problemen besproken, zoals het vinden van een balans tussen een scherpe inschrijving op MKI en het verminderen van risico door een veilige bandbreedte aan te nemen. Tijdens de tenderfase worden diverse aannames gemaakt en het kan zijn dat na een verdiepingsslag blijkt dat deze aanname niet haalbaar blijkt te zijn. Aangezien het tenderteam tijdens een tender in een concurrentiestrijd zit, zijn de marges heel klein en is de wil aanwezig om scherp in te schrijven. Dit betekent dat je af en toe te kleine marges aanhoudt en mogelijk een boete zal moeten betalen. Een extra punt volgens de experts is dat de MKI nog nooit doorslaggevend is geweest bij een ontwerpbeslissing en het werd gesuggereerd dat het zwaarder gewaardeerd zou moeten worden door klanten mochten ze milieubewustere projecten willen bouwen. Momenteel heeft prijs de overhand in de trade-off matrix.

Na het bespreken van de doelen van het MKI-proces werd er overgegaan op de afzonderlijke taken die uitgevoerd moeten worden binnen het proces. De eerste van deze is het definiëren van de scope. Van project tot project is er een aanzienlijke variabiliteit tussen de scope vanwege uiteenlopende wensen van de klant. Er wordt geconcludeerd dat het van cruciaal belang is om de scope grondig te doorgronden en dat deze niet klakkeloos overgenomen kan worden van een ander project. Hierbij wordt gesproken dat een project specifieke aanpak essentieel is en genomen beslissingen binnen het project ook daadwerkelijk worden nageleefd. Vervolgens wordt er nog kort besproken of het een mogelijkheid kan zijn om vanuit Mobilis zelf de scope te standaardiseren. Dit is niet mogelijk door de eerder besproken grote variabiliteit tussen de scope van diverse projecten. Het probleem wordt gediagnostiseerd als een gebrek aan projectgerichte strategie.

De volgende taak die besproken werd is het nemen van ontwerpbeslissingen. Ondanks dat er een nieuwe Trade-off matrix bestaat waarin de MKI is meegenomen, wordt deze niet altijd meegenomen. Er wordt geconcludeerd dat dit probleem lijkt op het vorige probleem. MKI kan wel in het proces of in de Trade-off Matrix staan, dan moet deze vervolgens wel toegepast worden. Dit soort taken kosten meer tijd, en worden daarom niet altijd goed uitgevoerd. Daarnaast voeren medewerkers deze taken niet vaak uit en kan het daardoor als lastig worden ervaren. Het achterliggende probleem kan daardoor ook een gebrek aan kennis zijn.

Hierna werd het verzamelen van de hoeveelheden besproken. Bij deze taak is het momenteel onduidelijk wie de verantwoordelijkheid heeft om deze taak uit te voeren. In de huidige werkwijze zijn drie verschillende rollen over het algemeen verantwoordelijk voor het verzamelen van de hoeveelheden, in de vorm van de modeleur, calculator en werkvoorbereider. Het uitvoeren van deze taak door elk van deze rollen heeft zijn voor- en nadelen. Daarnaast liggen in elk van de fases de nuances anders waardoor dit ook kan verschillen per projectfase. Er wordt geconcludeerd dat het probleem van de onduidelijke verantwoordelijkheid voor het uitvoeren van deze taak een belangrijk onderdeel is.

Vervolgens, wanneer de hoeveelheden verzameld zijn, moeten deze ook gecontroleerd worden. Uit de interviews is echter gekomen dat dit momenteel niet standaard gebeurt. Er werd beaamd dat tijdens de tenderfase alles heel snel gaat en er verschillende rekenhoeveelheden worden gebruikt. Het kan daardoor gebeuren dat er met verkeerde hoeveelheden wordt gerekend, zeker tijdens de laatste weken voor indiening. Er wordt hier opgebracht dat mocht er een bron zijn voor de hoeveelheden in de vorm van een 3D-model, deze controle niet meer benodigd is. Echter, de technologie en kennis vereist hiervoor is nog niet beschikbaar binnen Mobilis TBI.

Het volgende waarnaar gekeken werd binnen het proces was het verkrijgen van de LCA-waarden. Uit de interviews bleek dat er veel onduidelijkheid was over welke materialen LCA-waarden moesten krijgen en hoe deze, of eventuele ervaringsgetallen, gebruikt kunnen worden. Er wordt benoemd dat er een A3 is binnen Mobilis met standaard LCA-waardes en dat het bepalen van welke LCA's achterhaald moet worden, gedaan wordt met een dominantie analyse. Uit de combinatie van deze twee bevindingen wordt de diagnose gesteld dat er te weinig bekend is binnen het bedrijf over dat een dergelijke bibliotheek bijgehouden wordt. Er werd bij dit punt nog een extra probleem geïdentificeerd in de vorm van het openbaar maken van deze bibliotheek. Dit kon namelijk een slecht idee zijn aangezien het zou kunnen dat niet alle gegevens in de bibliotheek geldig zijn. Dit komt doordat deze kunnen verjaren. Ook bij dit punt moet daarnaast goed gekeken worden dat wanneer een waarde gebruikt wordt, hier ook aan voldaan wordt.

Als volgende taak werd het berekenen van de MKI-waarde besproken. Ook bij deze taak is er onduidelijkheid over de verantwoordelijkheid van de berekening en daarnaast heerst er een gevoel dat de berekening te complex is. Bij de experts wordt dit gezien als een gebrek aan kennis en ervaring. Het feit dat sommigen een MKI-berekening eens in de vijf jaar maken helpt daar niet bij. Vervolgens werd er door de experts nog benoemd dat er zorgvuldig om gegaan moet worden met de term verantwoordelijkheid. De persoon die een taak doet is niet per definitie verantwoordelijk. Er wordt bevestigd dat wie wat doet, wie welke verantwoordelijkheid heeft, en in welke fase een belangrijk probleem is om op te lossen in dit onderzoek. De laatste besproken taak is het verwerken van contractwijziging. Het erkennen dat de MKI van belang is tijdens een contractwijziging in het nieuwe proces wordt gezien als een belangrijk.

Appendix G: Summary Focus Group 2

De focusgroep begon met een beknopte update over de voortgang van het onderzoek en een vooruitblik op de te bespreken onderwerpen voor de tweede focusgroep. Dit werd gevolgd door een herhaling van de bevindingen uit de eerste focusgroep, waarin de problemen met de huidige situatie werden geïdentificeerd. Het herhalen van deze bevindingen werd gedaan omdat deze problemen werden omgezet in ontwerpprincipes tijdens deze focusgroep. Tijdens de herhaling van de gedefinieerde problemen zijn er geen onjuistheden ontdekt, waardoor we konden overgaan naar de uitleg van de methodes voor de tweede focusgroep.

Eerst werd de gekozen structuur van de ontwerpprincipes uitgelegd, die als volgt luidt:

"Voorzie het proces van (eigenschap) zodat gebruikers (activiteit) kunnen uitvoeren, rekening houdend met (randvoorwaarden)."

Deze structuur werd later aangepast tijdens de focusgroep naar:

"Voorzie met een gestandaardiseerd proces in het tot stand komen van (eigenschap), zodat gebruikers (activiteit) kunnen uitvoeren, rekening houdend met (randvoorwaarden)."

Naast de structuur werd ook de methode uitgelegd om de prioriteit van de ontwerpprincipes aan te geven, gebruikmakend van de MoSCoW-methode, die kort werd toegelicht. Vervolgens was het tijd voor het hoofddoel van de focusgroep: het definiëren en prioriteren van de ontwerpprincipes op basis van de problemen uit de eerste focusgroep. In het vervolg van deze samenvatting volgt een korte beschrijving van elk probleem, gevolgd door de gedefinieerde eis met bijbehorende prioritering.

Variabiliteit van de Scope in Projecten
Bij Mobilis TBI projecten leidt variabiliteit in de projectomvang, vaak door klantvereisten, tot onduidelijkheden en belemmert het de consistente MKI-beoordelingen. Dit probleem is vertaald naar het volgende ontwerpprincipe:

Voorzie met een gestandaardiseerd proces in het tot stand komen van de definitie van de MKI-scope (eigenschap) zodat het projectteam de MKI-scope nauwkeurig kan vaststellen (activiteit), rekening houdend met variabiliteit tussen de MKI-scope van projecten als gevolg van eisen, wensen en contractuele verplichtingen (randvoorwaarden). (Belangrijke ontwerpprincipe **(S)**)

Ongestructureerd Gebruik van Bandbreedtebepaling
In Mobilis TBI projecten vormt de ongestructureerde benadering van bandbreedtebepaling een uitdaging, vooral in de beginfase waar initiële MKI-waarden vaak geschat worden door gebrek aan details. Het behouden van een gestructureerde bandbreedte is essentieel om onzekerheden te beheersen, financiële boetes te voorkomen en milieudoelen te bereiken. Dit probleem is vertaald naar het volgende ontwerpprincipe:

Voorzie met een gestandaardiseerd proces in het tot stand komen van een besluitvorming moment voor risicobeoordeling met betrekking tot de MKI (eigenschap) zodat projectteams acceptabele risiconiveaus hebben bij indiening van tenders (activiteit), rekening houdend met EMVI-voordelen, boetes en prijsfluctuaties. (Belangrijke ontwerpprincipe **(S)**)

Onduidelijke Verantwoordelijkheid en Overdracht
Met betrekking tot taken binnen het MKI-proces is er verwarring over de verantwoordelijkheid, vooral bij het achterhalen van materiaalhoeveelheden en de berekening zelf. Dit probleem is vertaald naar het volgende ontwerpprincipe:

Voorzie met een gestandaardiseerd proces in het tot stand komen van een duidelijke toewijzing voor verantwoordelijkheden en taken (eigenschap) zodat projectteams de verantwoordelijkheid en uitvoering van taken leggen bij wie deze zou moeten liggen en overdrachtslijnen helder zijn (activiteit), rekening houdend met de krachten en zwaktes van de verschillende rollen en functies (randvoorwaarden). (Kritisch ontwerpprincipe **(M)**)

Gebrek aan Gestructureerde Controle van Hoeveelheden
Binnen het MKI-proces ontbreekt een gestructureerde aanpak voor het controleren van materiaalhoeveelheden, wat de nauwkeurigheid van milieu-impactbeoordelingen en kostenschattingen beïnvloedt. Dit probleem is vertaald naar het volgende ontwerpprincipe:

Voorzie met een gestandaardiseerd proces in het tot stand komen van een standaard benadering voor controle van materiaalhoeveelheden (eigenschap) zodat projectteams materiaalhoeveelheden consistent en nauwkeurig kunnen beheren en controleren (activiteit), rekening houdend met de korte tijdspan gedurende de tenderfase (randvoorwaarden). (Kritisch ontwerpprincipe **(M)**)

Onvoldoende Kennis en Ervaring met MKI
Mobilis TBI kampt met een gebrek aan kennis en ervaring in het MKI-proces, wat de volledige benutting van MKI in projectmanagement belemmert. Dit probleem is vertaald naar het volgende ontwerpprincipe:

Voorzie met een gestandaardiseerd proces in het tot stand komen van een moment voor kennisdeling (eigenschap) zodat projectteamleden expertise en begrip van MKI kunnen verwerven (activiteit), rekening houdend met de huidige onbalans in kennisverdeling (randvoorwaarden). (Uitgesloten ontwerpprincipe **(W)** → Aanbeveling voor beleid)

Gebrek aan Bewustzijn over het Bestaan van een LCA-bibliotheek
Mobilis TBI kampt met een gebrek aan bewustzijn over het bestaan van een LCA-bibliotheek en hoe deze te gebruiken. Dit probleem is vertaald naar het volgende ontwerpprincipe:

Voorzie met een gestandaardiseerd proces in het tot stand komen van aanwijzingen voor het gebruik van de LCA-bibliotheek (eigenschap) zodat projectteams weten van het bestaan van de LCA-bibliotheek en deze kunnen gebruiken via de duurzaamheidscoördinator (activiteit), rekening houdend met het feit dat de duurzaamheidscoördinator altijd een adviserende functie heeft bij deze activiteit (randvoorwaarden). (Belangrijke ontwerpprincipe **(S)**)

Milieudoelstellingen Mobilis TBI
Bij Mobilis TBI is er een behoefte aan duidelijke MKI-doelen voor alle projecten, aangezien duurzaamheid een essentieel aspect is. Overwegingen om MKI-beoordelingen uit te voeren voor alle projecten vereisen interne doelen voor efficiëntie. Dit probleem is vertaald naar het volgende ontwerpprincipe:

Voorzie met een gestandaardiseerd proces in het tot stand komen van een input voor het definiëren van interne MKI-doelstellingen (eigenschap) zodat projectteams zich kunnen afstemmen op intern opgelegde duurzaamheidsdoelstellingen (activiteit), rekening houdend met effectievere meting, beperking van de milieueffecten van bouwprojecten en het winstoogmerk (randvoorwaarden). (Kritisch ontwerpprincipe **(M)**)

Beperkte Nadruk van de Klant op Milieueffecten
De klant legt vaak te weinig nadruk op milieueffecten. Ondanks de vaak aangevraagde MKI-berekeningen, beïnvloeden prijsafwegingen nog steeds de besluitvorming, wat kostenefficiëntie boven milieuduurzaamheid plaatst. Daarnaast staan er in diverse gevallen tegenstrijdige eisen en

wensen in het contract met betrekking tot duurzaamheid. Dit probleem is vertaald naar het volgende ontwerpprincipe:

Voorzie met een gestandaardiseerd proces in het tot stand komen van overlegmomenten met de klant in het ontwerpproces (eigenschap) zodat projectteams milieubewustere ontwerpbeslissingen met de klant kunnen valideren en verifiëren (activiteit), rekening houdend met tegenstrijdigheden tussen esthetische, technische en duurzaamheidseisen (randvoorwaarden). (Belangrijke ontwerpprincipe **(S)**)

Gebrek aan Projectgericht Werken met Betrekking tot de MKI
Projectteams missen een duidelijke focus op projectgerichtheid bij MKI-aspecten. Gebrek aan projectgerichte focus leidt tot inefficiëntie en gemiste kansen. Doordat de scope tussen projecten varieert is er geen uniforme oplossing. Dit probleem is vertaald naar het volgende ontwerpprincipe:

Voorzie met een gestandaardiseerd proces in het tot stand komen van een transformatieplan voor het bevorderen van een op projecten gerichte cultuur (eigenschap) zodat projectteams projectgerichte benaderingen kunnen omarmen (activiteit), rekening houdend met de huidige manier van werken (randvoorwaarden). (Uitgesloten ontwerpprincipe **(W)**)

Gebrek aan een Enkele Bron voor Materiaalhoeveelheden in Aanbesteding
Bij Mobilis TBI ontbreekt momenteel een enkele bron voor materiaalhoeveelheden in aanbestedingen, wat leidt tot verschillen door het gebruik van verschillende tools. Het doel is om een betrouwbare bron te hebben om handmatige invoer te verminderen en fouten te voorkomen. Technische uitdagingen en complexiteit van bouwmaterialen vormen echter obstakels. Dit probleem is vertaald naar het volgende ontwerpprincipe:

Voorzie met een gestandaardiseerd proces in het tot stand komen van een gecentraliseerde materiaalhoeveelheidsbepaling (eigenschap) zodat projectteams hoeveelheden uit een model kunnen halen (activiteit), rekening houdend met de huidige technologische mogelijkheden (randvoorwaarden). (Optionele ontwerpprincipe **(C)**)

Gebrek aan Standaard Controle van de MKI bij VTW's
Mobilis TBI staat momenteel voor een aanzienlijke uitdaging met betrekking tot het ontbreken van een gestandaardiseerde controle voor het beheren van de implicaties van MKI tijdens contractuele wijzigingen. Het probleem komt aan het licht wanneer aanpassingen aan het contract worden geïnitieerd en de gevolgen van MKI niet consequent worden aangepakt en gecontroleerd. Dit probleem is vertaald naar het volgende ontwerpprincipe:

Voorzie met een gestandaardiseerd proces in het tot stand komen van een controle element van het MKI-aspect binnen een VTW (eigenschap), zodat projectteams op een standaard wijze de gevolgen van de VTW meenemen in de MKI-berekening (activiteit), rekening houdend met de huidige manier waarop VTW's worden uitgevoerd (randvoorwaarden). (Kritisch ontwerpprincipe **(M)**)

Appendix H: Summary Focus Group 3

De derde focusgroep begon met een korte presentatie waarin de onderzoeksmethode en bevindingen van de eerste twee focusgroepen werden samengevat. Hierop volgde een uitleg van de geplande demonstratie van het nieuwe MKI-proces tijdens de aanbestedingsfase. De demonstratie omvatte een stapsgewijze bespreking van het proces, met zowel een overzicht van het gehele proces als een diepgaande analyse van elke afzonderlijke stap.

Tijdens de bespreking en aanpassing van het proces kwamen verschillende aspecten naar voren. Zo werd voorgesteld om het inputdocument 'MKI-doelstelling klant' te hernoemen naar 'Aanbestedingsdossier klant', aangezien de eerdere benaming niet allesomvattend is. Voor het bepalen van de MKI-scope werden aanpassingen voorgesteld met betrekking tot de RASCI, waarbij verantwoordelijkheden werden heroverwogen en extra ondersteunende rollen werden toegevoegd. Voor alle activiteiten zijn de RASCI gedurende de demonstratie besproken en heroverwogen. Deze worden niet allen benoemd in deze samenvatting.

Bij het behandelen van tegenstrijdigheden in contracteisen werden verduidelijkingen en aanpassingen voorgesteld, evenals voor de actie 'toekennen scope onderdelen aan teamleden' en de registerinput van de LCA-bibliotheek. Het besproken aspect na dit punt betrof het iteratieve deel van de MKI-berekening, waarbij een extra stap werd voorgesteld die de volgorde van daaropvolgende acties en beslismomenten licht zou wijzigen. De toegevoegde stap betreft het uitvoeren van een berekening met DuBoCalc-waarden, gevolgd door een beslissingsmoment om te bepalen of het ontwerp met deze waarden al voldoet aan de gewenste waarde. Vervolgens wordt op basis van een impactanalyse besloten welke optimalisatiemaatregelen moeten worden genomen, zoals het gebruik van een bestaande LCA, het implementeren van een alternatieve ontwerpoplossing, of het opvragen van een EPD's bij de toeleverancier. Als de MKI-waarde al aan de gewenste norm voldoet, wordt het iteratieve deel van de berekening overgeslagen. Een laatste aanpassing tijdens de demonstratie van het aanbestedingsproces betrof de naamswijziging van het outputdocument van de MKI-berekening tender naar MKI-rapportage tender, aangezien alleen de berekening niet alle benodigde informatie omvat.

De volgende activiteit van deze focusgroep betrof de demonstratie van het ontwerp- en realisatie-MKI-proces. Net als bij het andere proces werd het proces eerst in grote lijnen doorgenomen om vervolgens specifieke stappen nader te bespreken, met name de stappen die verschillen ten opzichte van het eerder behandelde tenderproces. Kort werd de RASCI besproken in vergelijking met het tenderproces en vervolgens werd er speciale aandacht besteed aan het koppelen van de processen aan het MKI-proces voor de ontwerp- en realisatiefase. Het MKI-proces moet worden gekoppeld aan het voorlopig ontwerp, definitief ontwerp, uitvoering ontwerp en realisatie processen. Er werd besproken hoe deze koppeling kon plaatsvinden en dat alle benodigde MKI-rapportages in het proces waren opgenomen. Er werd besloten om een extra inputproces toe te voegen voor de uitvoering, waarbij uiteindelijk werd vastgesteld dat deze input afkomstig moest zijn van de werkvoorbereiding. Tijdens de demonstratie werd ook opgemerkt dat een outputdocument uit het oorspronkelijke proces niet langer relevant was voor dit specifieke proces, en dat de naam van de actie 'actualiseren hoeveelheden' moest worden aangepast.

Om de derde focusgroep af te ronden, werd een evaluatie uitgevoerd waarbij werd besloten hoe de geïdentificeerde problemen waren opgelost. In vier categorieën - operationaliteit, efficiëntie, algemeenheid en gebruiksvriendelijkheid - werden de problemen 1, 2, 3, 4 en 7 volgens de experts als adequaat opgelost beschouwd. Er waren echter nog vragen over de daadwerkelijke implementatie van de oplossingen bij sommige van deze problemen. Probleem 8, met de toevoeging van de MKI-doelstelling van Mobilis, werd als positief beoordeeld, maar er werden vragen gesteld over de praktische uitvoering tijdens projecten aangezien de daadwerkelijke doelstellingen nog moeten worden vastgesteld. Probleem 5 wordt aangepakt in het contractwijzigingsproces, dat op het moment van de derde focusgroep nog niet was aangepast. Probleem 9 is gedeeltelijk opgelost, met een toegevoegde actie in het nieuwe proces om een dialoog aan te gaan bij onduidelijkheden in contracteisen. Echter is de klant hier altijd leidend en kan dit probleem niet volledig verholpen worden met de creatie van dit nieuwe MKI-proces. Probleem 11 werd tot nu toe slechts aangeduid als een intentie om materiaalhoeveelheden in één bron te verzamelen, maar verdere uitvoering vereist nader onderzoek. Voor de laatste twee problemen, probleem 6 en 10, was tijdens focusgroep 2 besloten om geen directe oplossingen te implementeren, met het oog op lange termijn verbeteringen door de creatie van dit nieuwe proces.

Appendix I: Final Initiation MKI Process

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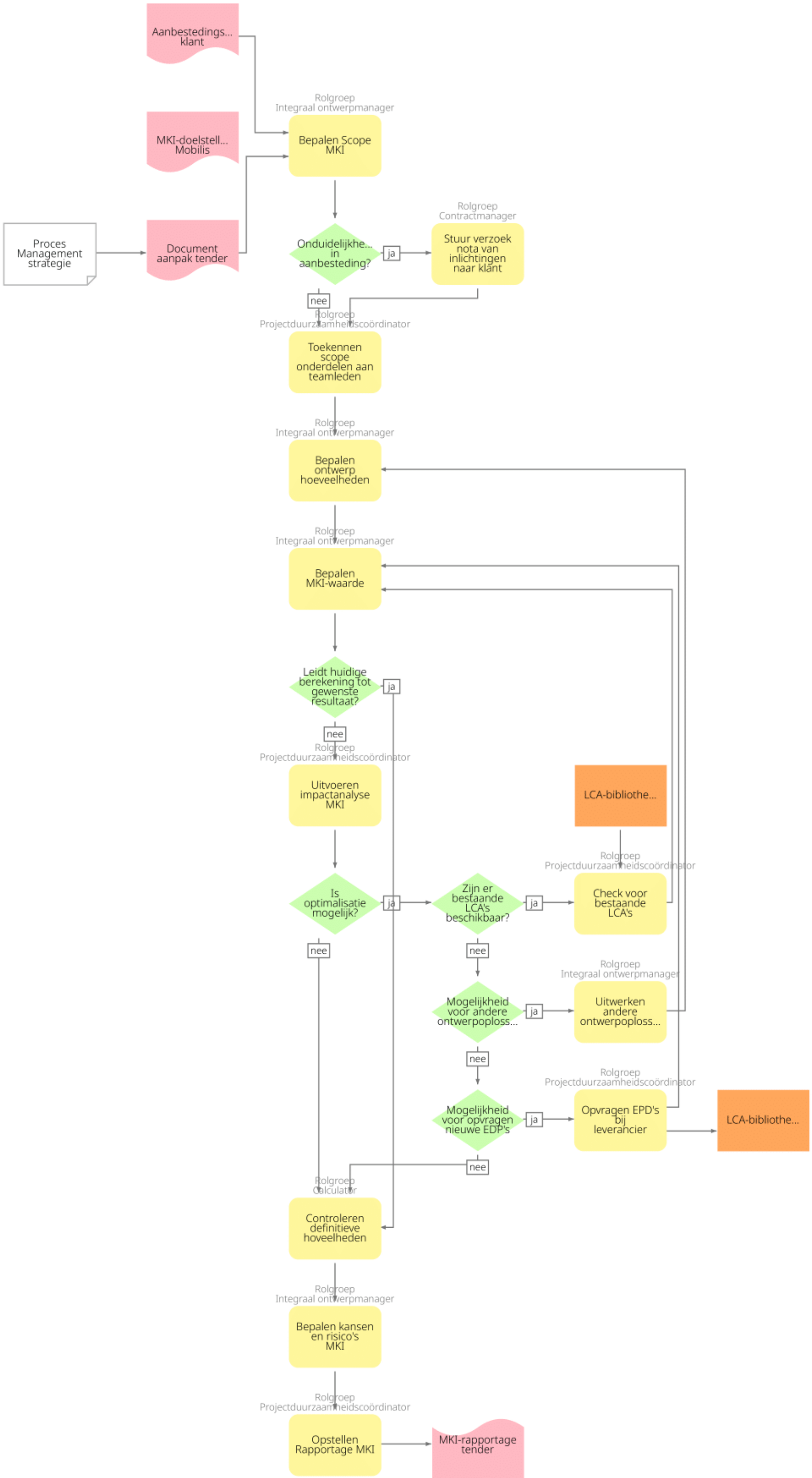
Procesflowrapport
Conceptversie - 26-01-2024

1.1.1.1 Opzetten MKI berekening

Verantwoordelijke rol	Projectduurzaamheidscoördinator
Beschrijving	Het doel van dit proces is het opzetten van de MKI-waarde die benodigd is voor de aanbieding aan de klant om de impact van de werkzaamheden te verminderen.

Procesflow "1.1.1.1 Opzetten MKI berekening"



Procesbeschrijving "1.1.1.1 Opzetten MKI berekening"

1. Aanbestedingsdossier klant

2. MKI-doelstelling Mobilis

3. Proces Management strategie

4. Document aanpak tender

5. Bepalen Scope MKI

Verantwoordelijke rol Integraal ontwerpmanager

Beschrijving Het proces begint met het bepalen van de MKI-scope, wat de grondslag vormt voor alle daaropvolgende acties. Het is cruciaal om zorgvuldig te analyseren welke materialen en taken binnen de MKI-berekening vallen en welke daarbuiten blijven.

RASCI

Responsible	Integraal ontwerpmanager
Accountable	Tendermanager
Support	• Projectduurzaamheidscoördinator • Contractmanager

6. Onduidelijkheden in aanbesteding?

Beschrijving In diverse gevallen kan het voorkomen dat in de scope onduidelijkheden of tegenstrijdigheden zitten die mogelijk verder toegelicht moeten worden door de klant. Mocht dit het geval zijn kan er bij de klant om een nota van inlichtingen verzocht worden om verduidelijking te brengen aan desbetreffende eis.

7. Stuur verzoek nota van inlichtingen naar klant

Verantwoordelijke rol Contractmanager

Beschrijving Tijdens een aanbesteding is het doorgaans niet mogelijk om wijzigingen aan te brengen in de aanbesteding bij de klant. Het is wel mogelijk om bij onduidelijkheden en tegenstrijdigheden in de aanbestedingseisen een verzoek voor een nota van inlichtingen naar de klant te sturen om de aanbestedingseisen te verduidelijken.

RASCI

Responsible	Contractmanager
Accountable	Tendermanager
Support	• Projectduurzaamheidscoördinator • Integraal ontwerpmanager • Calculator

8. Toekennen scope onderdelen aan teamleden

Verantwoordelijke rol	Projectduurzaamheidscoördinator
Beschrijving	In projecten kan het voorkomen dat de verantwoordelijkheid voor het berekenen van de MKI wordt opgesplitst (bijvoorbeeld voor kunstwerken en grondwerken). Gedurende deze actie moet er voor gezorgd worden dat scope onderdelen correct worden toegewezen aan de juiste verantwoordelijken binnen het projectteam.
RASCI	

Responsible	Projectduurzaamheidscoördinator
Accountable	Tendermanager
Support	• Calculator • Werkvoorbereider • Integraal ontwerpmanager

9. Bepalen ontwerp hoeveelheden

Verantwoordelijke rol	Integraal ontwerpmanager
Beschrijving	Op basis van het tenderontwerp zijn er hoeveelheden materiaal benodigd voor de constructie van het project. Deze hoeveelheden zullen in samenspraak met de calculator en de input van de ontwerpteams bepaald worden om hierop de MKI-berekening te baseren. Idealiter worden de hoeveelheden verzameld in een enkele bron.
RASCI	

Responsible	Integraal ontwerpmanager
Accountable	Tendermanager
Support	• Calculator • Modelleur • Werkvoorbereider • Projectduurzaamheidscoördinator • Constructeur

10. Bepalen MKI-waarde

Verantwoordelijke rol	Integraal ontwerpmanager
Beschrijving	Op basis van het actuele ontwerp en MKI-waarde voor de materialen wordt een MKI-waarde vastgesteld, zowel per deelgebied/deelsysteem als voor het geheel. Gedurende de eerste iteratie zal dit gebeuren met DuBoCalc waarden. Iteratief zullen optimalisaties worden uitgevoerd waardoor het ontwerp en de MKI-waarden voor de materialen veranderen tot een gewenst resultaat is bereikt.
RASCI	

Responsible	Integraal ontwerpmanager
Accountable	Tendermanager
Support	• Calculator • Werkvoorbereider • Modelleur • Constructeur

11. Leidt huidige berekening tot gewenste resultaat?

Beschrijving — Na het berekenen van de MKI voor het project moet bekeken worden of de huidige berekening leidt tot een gewenst resultaat met betrekking tot de MKI. Mocht dit niet het geval zijn moet er aan de hand van een impactanalyse bekeken worden of optimalisatie van de MKI mogelijk is.

12. Uitvoeren impactanalyse MKI

Verantwoordelijke rol — Projectduurzaamheidscoördinator

Beschrijving — Op basis van de bepaalde MKI-waarde van het tenderontwerp wordt een impactanalyse uitgevoerd. Hierbij wordt gekeken welke onderdelen van het ontwerp de grootste impact hebben op de MKI-waarde en of deze verbeterd kunnen worden door het gebruiken van een andere ontwerpoplossing of het toepassen van een product specifieke LCA.

RASCI

Responsible	Projectduurzaamheidscoördinator
Accountable	Tendermanager
Support	Integraal ontwerpmanager

13. Is optimalisatie mogelijk?

Beschrijving — Aan de hand van de impactanalyse moet gekeken worden of er optimalisaties aan de MKI-berekening mogelijk zijn door middel van een andere ontwerpoplossing of het toepassen van bestaande of nieuwe LCA's.

14. Zijn er bestaande LCA's beschikbaar?

15. LCA-bibliotheek

16. Check voor bestaande LCA's

Verantwoordelijke rol — Projectduurzaamheidscoördinator

Beschrijving — Voor het verbeteren van de MKI-waarde is het mogelijk om te kijken naar de beschikbaarheid van product specifieke LCA's welke een betere waarde hebben dan de standaard LCA's uit DuBoCalc.

RASCI

Responsible	Projectduurzaamheidscoördinator
Accountable	Tendermanager
Support	Inkoop

17. Mogelijkheid voor andere ontwerpoplossing?

18. Uitwerken andere ontwerpoplossing

Verantwoordelijke rol Integraal ontwerpmanager

Beschrijving Het ontwerpteam ontwikkelt potentiële alternatieve en duurzamere ontwerpoplossingen om de MKI te verlagen, met behoud van de overige vereisten.

RASCI

Responsible	Integraal ontwerpmanager
Accountable	Tendermanager
Support	• Modelleur • Projectduurzaamheidscoördinator • Constructeur • Werkvoorbereider • Calculator

19. Mogelijkheid voor opvragen nieuwe EDP's

20. Opvragen EPD's bij leverancier

Verantwoordelijke rol Projectduurzaamheidscoördinator

Beschrijving Indien het niet mogelijk is om voor een andere ontwerpoplossing te kiezen is het nog een mogelijkheid om de waarde van de MKI te verlagen aan de hand van EPD's (Environmental Product Declaration). Deze zullen dan opgevraagd moeten worden bij de toeleverancier.

RASCI

Responsible	Projectduurzaamheidscoördinator
Accountable	Tendermanager
Support	• Werkvoorbereider • Inkoop

21. LCA-bibliotheek

22. Controleren definitieve hoeveelheden

Verantwoordelijke rol Calculator

Beschrijving Bij afronding van de MKI-berekening is het van belang dat de hoeveelheden die gebruikt zijn voor deze berekening overeenkomen met de hoeveelheden die gebruikt zijn bij het opzetten van de begroting.

RASCI

Responsible	Calculator
Accountable	Tendermanager
Support	• Werkvoorbereider • Modelleur

23. Bepalen kansen en risico's MKI

Verantwoordelijke rol	Integraal ontwerpmanager
Beschrijving	Bij indiening van de tender wordt een marge toegevoegd aan de MKI-waarde verkregen vanuit de berekening. Deze moet bepaald worden op basis van het risico dat aanwezig is op wijzingen van de MKI-waarde bij dit project.
RASCI	

Responsible	Integraal ontwerpmanager
Accountable	Tendermanager
Support	Projectduurzaamheidscoördinator

24. Opstellen Rapportage MKI

Verantwoordelijke rol	Projectduurzaamheidscoördinator
Beschrijving	De MKI-berekening en de daarbij horende onderbouwing vanuit de tender wordt verzameld bij het opstellen van de MKI-rapportage
RASCI	

Responsible	Projectduurzaamheidscoördinator
Accountable	Tendermanager
Support	• Werkvoorbereider • Modelleur • Calculator

25. MKI-rapportage tender

Appendix J: Final Planning/Realization MKI Process

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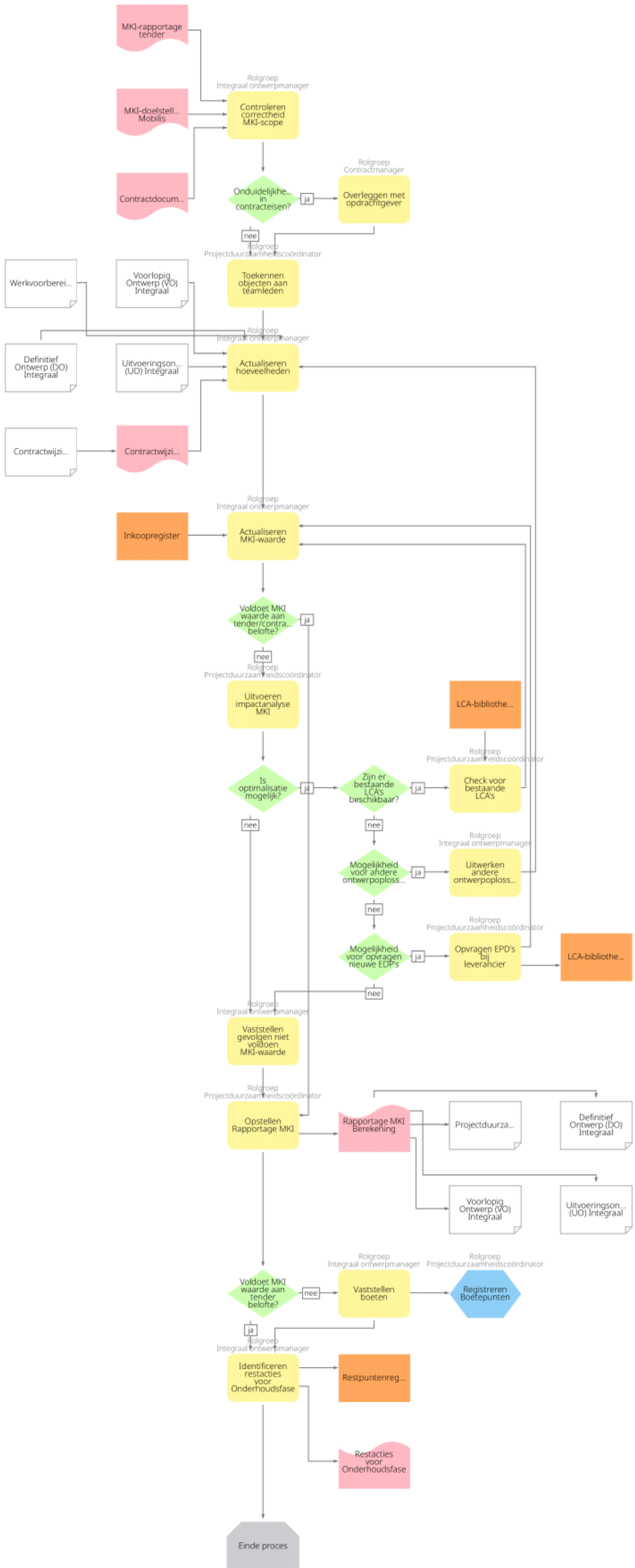
Procesflowrapport
Conceptversie - 26-01-2024

1.1.1.2 Bewaken MKI-waarde

Verantwoordelijke rol	Projectduurzaamheidscoördinator
Beschrijving	Het doel van dit proces is het bewaken van de opgestelde MKI-waarde tijdens de aanbesteding, die nu contractueel is opgelegd aan het project.

Procesflow "1.1.1.2 Bewaken MKI-waarde"



Procesbeschrijving "1.1.1.2 Bewaken MKI-waarde"

1. MKI-rapportage tender

2. MKI-doelstelling Mobilis

3. Contractdocumenten

4. Controleren correctheid MKI-scope

Verantwoordelijke rol Integraal ontwerpmanager

Beschrijving Bij het starten van het project is het van belang om te controleren dat de scope die gebruikt is voor de MKI-berekening in de tender in de huidige projectfase nog steeds correct is.

RASCI

Responsible	Integraal ontwerpmanager
Accountable	Projectmanager
Support	• Projectduurzaamheidscoördinator • Contractmanager

5. Onduidelijkheden in contracteisen?

Beschrijving In diverse gevallen kan het voorkomen dat in de contracteisen onduidelijkheden of tegenstrijdigheden zitten die mogelijk verder toegelicht moeten worden door de klant. Mocht dit het geval zijn kan een vergadering ingepland worden om verduidelijking te brengen aan desbetreffende eis.

6. Overleggen met opdrachtgever

Verantwoordelijke rol Contractmanager

Beschrijving Bij onduidelijkheden of tegenstrijdigheden van eisen in het contract wordt een overleg met de opdrachtgever ingepland om desbetreffende eis te bespreken en eventueel tot een andere oplossing te komen.

RASCI

Responsible	Contractmanager
Accountable	Projectmanager
Support	• Projectduurzaamheidscoördinator • Integraal ontwerpmanager • Calculator

7. Toekennen objecten aan teamleden

Verantwoordelijke rol Projectduurzaamheidscoördinator

Beschrijving In projecten kan het voorkomen dat de verantwoordelijkheid voor het berekenen van de MKI wordt opgesplitst (bijvoorbeeld voor kunstwerken en grondwerken). Gedurende deze actie moet er voor gezorgd worden dat scope onderdelen correct worden toegewezen aan de juiste verantwoordelijken binnen het projectteam.

RASCI

Responsible	Projectduurzaamheidscoördinator
Accountable	Projectmanager
Support	• Calculator • Integraal ontwerpmanager • Werkvoorbereider

8. Werkvoorbereiding

9. Voorlopig Ontwerp (VO) Integraal

10. Definitief Ontwerp (DO) Integraal

11. Uitvoeringsontwerp (UO) Integraal

12. Contractwijzigingen

13. Contractwijziging

14. Actualiseren hoeveelheden

Verantwoordelijke rol Integraal ontwerpmanager

Beschrijving Op basis van de ontwikkeling tijdens de ontwerpfase kunnen de hoeveelheden wijzigen. Periodiek zal in samenspraak met de calculator en met de input van de ontwerpteams deze wijzigingen worden meegenomen in de berekening. Oftewel, de hoeveelheden vanuit ontwerp en realisatie worden hier geactualiseerd. Het is hierbij van belang bij deze actualisatie dat de materiaal hoeveelheden overeen komen met de andere berekeningen waar materiaal hoeveelheden zijn gebruikt binnen het project. Idealiter worden de hoeveelheden verzameld in een enkele bron.

RASCI

Responsible	Integraal ontwerpmanager
Accountable	Projectmanager
Support	• Calculator • Modelleur • Projectduurzaamheidscoördinator • Werkvoorbereider • Constructeur

15. Inkoopregister

16. Actualiseren MKI-waarde

Verantwoordelijke rol Integraal ontwerpmanager

Beschrijving Op basis van het actuele ontwerp en MKI-waarde voor de materialen wordt een MKI-waarde vastgesteld, zowel per deelgebied/deelsysteem als voor het geheel.

RASCI

Responsible	Integraal ontwerpmanager
Accountable	Projectmanager
Support	• Calculator • Werkvoorbereider • Modelleur • Constructeur

17. Voldoet MKI waarde aan tender/contract belofte?

Beschrijving Na het berekenen van de MKI voor het project moet bekeken worden of de huidige berekening leidt tot een gewenst resultaat dat voldoet aan de contract belofte. Mocht dit niet het geval zijn moet er aan de hand van een impactanalyse bekeken worden of optimalisatie van de MKI mogelijk is.

18. Uitvoeren impactanalyse MKI

Verantwoordelijke rol Projectduurzaamheidscoördinator

Beschrijving Op basis van de bepaalde MKI-waarde van het huidige ontwerp wordt een impactanalyse uitgevoerd. Hierbij wordt gekeken welke onderdelen van het ontwerp de grootste impact hebben op de MKI-waarde en of deze verbeterd kunnen worden door het gebruiken van een andere ontwerpoplossing of het toepassen van een product specifieke LCA.

RASCI

Responsible	Projectduurzaamheidscoördinator
Accountable	Projectmanager
Support	Integraal ontwerpmanager

19. Is optimalisatie mogelijk?

Beschrijving Aan de hand van de impactanalyse moet gekeken worden of er optimalisaties aan de MKI-berekening mogelijk zijn door middel van een andere ontwerpoplossing of het toepassen van bestaande of nieuwe LCA's.

20. Zijn er bestaande LCA's beschikbaar?

21. LCA-bibliotheek

22. Check voor bestaande LCA's

Verantwoordelijke rol	Projectduurzaamheidscoördinator
Beschrijving	Voor het verbeteren van de MKI-waarde is het mogelijk om te kijken naar de beschikbaarheid van product specifieke LCA's welke een betere waarde hebben dan de standaard LCA's uit DuBoCalc.
RASCI	

Responsible	Projectduurzaamheidscoördinator
Accountable	Projectmanager
Support	Inkoop

23. Mogelijkheid voor andere ontwerpoplossing?

24. Uitwerken andere ontwerpoplossing

Verantwoordelijke rol	Integraal ontwerpmanager
Beschrijving	Het ontwerpteam ontwikkelt potentiële alternatieve en duurzamere ontwerpoplossingen om de MKI te verlagen, met behoud van de overige vereisten.
RASCI	

Responsible	Integraal ontwerpmanager
Accountable	Projectmanager
Support	• Modelleur • Projectduurzaamheidscoördinator • Constructeur • Werkvoorbereider • Calculator

25. Mogelijkheid voor opvragen nieuwe EDP's

26. Opvragen EPD's bij leverancier

Verantwoordelijke rol	Projectduurzaamheidscoördinator
Beschrijving	Indien er geen bestaande LCA's beschikbaar zijn of de mogelijkheid voor een andere ontwerpoplossing, is het nog een mogelijkheid om de waarde van de MKI te verlagen aan de hand van EPD's (Environmental Product Declaration). Deze EPD's zullen opgevraagd moeten worden bij de toeleverancier.
RASCI	

Responsible	Projectduurzaamheidscoördinator
Accountable	Projectmanager
Support	• Werkvoorbereider • Inkoop

27. LCA-bibliotheek

28. Vaststellen gevolgen niet voldoen MKI-waarde

Verantwoordelijke rol Integraal ontwerpmanager

Beschrijving Indien het niet mogelijk is de vastgestelde contracteis te behalen moet worden vastgesteld worden wat de gevolgen zijn van het niet voldoen aan de in het contract vastgestelde MKI-eis.

RASCI

Responsible	Integraal ontwerpmanager
Accountable	Projectmanager
Support	• Projectduurzaamheidscoördinator • Contractmanager

29. Opstellen Rapportage MKI

Verantwoordelijke rol Projectduurzaamheidscoördinator

Beschrijving De MKI-berekening en de daarbij horende onderbouwing wordt per deadline moment en/of periodiek verzameld bij het opstellen van de MKI-rapportage.

RASCI

Responsible	Projectduurzaamheidscoördinator
Accountable	Projectmanager
Support	• Werkvoorbereider • Modelleur • Calculator

30. Rapportage MKI Berekening

31. Projectduurzaamheidsprestaties

32. Definitief Ontwerp (DO) Integraal

33. Voorlopig Ontwerp (VO) Integraal

34. Uitvoeringsontwerp (UO) Integraal

35. Voldoet MKI waarde aan tender belofte?

36. Vaststellen boeten

Verantwoordelijke rol Integraal ontwerpmanager

Beschrijving In het geval dat een boete vastgesteld wordt, dan zal deze meegenomen worden in de financiële afwikkeling van het project.

RASCI

Responsible	Integraal ontwerpmanager
Accountable	Projectmanager
Support	• Contractmanager • Projectduurzaamheidscoördinator

37. Registreren Boetepunten

Verantwoordelijke rol Projectduurzaamheidscoördinator

RASCI

Responsible	Projectduurzaamheidscoördinator
Accountable	Projectmanager

38. Identificeren restacties voor Onderhoudsfase

Verantwoordelijke rol Integraal ontwerpmanager

Beschrijving Er zijn twee type restacties welke geïdentificeerd kunnen worden. Enerzijds zijn er de restacties welke tijdens onderhoud opgepakt gaan worden, anderzijds zijn er restacties die nog door de realisatiefase opgelost zullen moeten worden.

RASCI

Responsible	Integraal ontwerpmanager
Accountable	Projectmanager
Support	Projectduurzaamheidscoördinator

39. Restpuntenregister

40. Restacties voor Onderhoudsfase

41. Einde proces

Appendix K: Design Process from Identified Problems to Evaluation for all Identified Problems

Problem		Design Principle		Priority	Design Feature		Sensus Method Design Feature		Evaluation: Operationality	Evaluation: Efficiency	Evaluation: Generality	Evaluation: Ease of Use
1	Scope variability between projects	1	Enable with a standardized process for the creation of the (structured) definition of the MKI scope **(property)**, so that project teams can accurately determine the MKI scope **(activity)**, considering variability between the MKI scopes of projects due to requirements, preferences, and contractual obligations **(preconditions)**.	Should	1.1	Implement a task where the MKI-scope is defined in the initiation process.	1.1	Action: 'Determine scope MKI' in the initiation process.	3	4	5	3
					1.2	Implement a task where it is checked by the project team if the scope defined in the initiation process is still accurate with the current state of the project	1.2	Action: 'Check correctness of MKI scope' in the planning/realization process.				
2	Unstructured use of bandwidth determination	2	Enable with a standardized process for the creation of a decision-making moment for risk assessment related to the MKI **(property)**, so that project teams use acceptable risk levels when submitting tenders **(activity)**, considering EMVI benefits, penalties, and price fluctuations **(preconditions)**.	Should	2	Implement a task in the initiation process where it is decided what bandwidth should be used for the tender bid	2	Action: 'Determining opportunities and risks MKI' in the initiation process.	4	4	5	3
3	Unclear responsibility and handover	3	Enable with a standardized process for the creation of a clear assignment of responsibilities and tasks **(property)**, so that project teams allocate responsibility and task execution to the appropriate individuals with clear lines of transfer **(activity)**, considering the strengths and weaknesses of different roles and functions **(preconditions)**."	Must	3.1	Both processes should follow a logically sequenced order in performing the necessary tasks.	3.1a	The tasks, input documents, etc. are logically sequenced following the Sensus-method in the initiation process.	5	5	5	5
							3.1b	The tasks, input documents, etc. are logically sequenced following the Sensus-method in the planning/realization process.				
					3.2	Both processes should indicate the RASCI of the necessary tasks clearly.	3.2a	RASCI is used to indicate the responsibility, accountability, etc. where necessary for each task in the initiation process.				
							3.2b	RASCI is used to indicate the responsibility, accountability, etc. where necessary for each task in the planning/realization process.				

	Problem		Design Principle	Priority		Design Feature		Sensus Method Design Feature	Operationality	Efficiency	Generality	Ease of Use
4	Lack of structured control of quantities	4	Enable with a standardized process for the creation of a standard approach for the control of material quantities **(property)**, so that project teams can consistently and accurately manage and control material quantities **(activity)**, considering the short time span during the tender phase **(preconditions)**.	Must	4.1	Implement a task where the quantities of the design are controlled in the initiation process	4.1	Action: 'Check final quantities' in initiation process.	5	4	5	4
					4.2	Implement a task where the quantities of the design are controlled in the planning/realization process	4.2	Description in action 'Update material quantities' in the planning/realization process, where is described that after gathering the material quantities for the design should be checked.				
5	Lack of structured control of MKI during request of change	5	Enable with a standardized process for the creation of a control element of the MKI within a request to change **(property)**, so that project teams systematically incorporate the consequences of the request to change into the MKI-calculation **(activity)**, considering the current way requests of change are executed **(preconditions)**.	Must	5	Implement an extra indication that the MKI should be checked during a change of contract	5	Description in the change of contract process (so, neither of the MKI processes) for a check whether the change of contract has influence on the MKI aspect of the project.	2	2	1	1
6	Insufficient knowledge and experience with MKI	6	Enable with a standardized process for the creation of a moment for knowledge sharing **(property)**, so that project team members can acquire expertise and understanding of MKI **(activity)**, considering the current imbalance in knowledge distribution **(preconditions)**.	Won't		-		-	-	-	-	-
7	Lack of awareness regarding the existence of a LCA library	7	Enable with a standardized process for the creation of instructions for the use of the LCA library **(property)**, so that project teams are aware of the existence of the LCA library and can utilize it through the sustainability coordinator **(activity)**, considering that the sustainability coordinator always has an advisory role in this activity **(preconditions)**.	Should	7.1	Implement a task where the impact of the design is analyzed in order to see which design parts have the highest impact which could be	7.1a	Action: 'Perform MKI impact analysis' in initiation process.	4	4	4	4
							7.1b	Action: 'Perform MKI impact analysis' in planning/realization process.				
					7.2	Implement a task where it is checked whether there are MKI-values which can be extracted from the LCA library for the design of the current project	7.2a	Action: 'Check for existing LCA's' in initiation process.				
							7.2b	Archive: 'LCA Library' in initiaton process.				
							7.2c	Archive: 'LCA Library' in planning/realization process.				

Problem		Design Principle		Priority	Design Feature		Sensus Method Design Feature		Evaluation			
									Operationality	Efficiency	Generality	Ease of Use
8	Environmental goals Mobilis TBI	8	Enable with a standardized process for the creation of input for defining internal MKI objectives **(property)**, so that project teams can align with internally imposed sustainability goals **(activity)**, considering more effective measurement, mitigation of the	Must	8	Create an input in which the MKI goals from Mobilis TBI are integrated	8a 8b	Document: 'MKI goal Mobilis' in initiation process. Document: 'MKI goal Mobilis' in planning/realization process.	4	4	3	3
9	Limited client emphasis on environmental impact in procurement	9	Enable with a standardized process for the creation of consultation moments with the client in the design process **(property)**, so that project teams can validate and verify environmentally conscious design decisions with the customer **(activity)**, considering conflicts between aesthetic, technical, and sustainability requirements **(preconditions)**.	Should	9	Implement a moment in both processes where it is decided on whether communication with the client is necessary in regards to the MKI requirements	9a 9b	Choice: 'Unclarities in tender?' in initiation process. In case this question is true: Action: 'Request note of information to client'. Choice: 'Unclarities in contract?' in planning/realization process. In case this question is true: Action: 'Consult with client'.	2	2	3	2
10	Lack of project focused employees for MKI	10	Enable with a standardized process for the creation of a transformation plan to promote a project-focused culture **(property)**, so that project teams can embrace project-oriented approaches **(activity)**, considering the current way of working **(preconditions)**.	Won't					-	-	-	-
11	Lack of single source for material quantities in tenders	11	Enable with a standardized process for the creation of a centralized material quantity determination **(property)**, so that project teams can extract quantities from a single model **(activity)**, considering the current technological capabilities **(preconditions)**.	Could	11	Implement an indication in which it is stated that the quantities of the design are ideally centralized in one source	11a 11b	Description in action: 'Determine material quantities design' in initiation process which indicates that if possible the quantities should be centralized into one source. Description in action: 'Update material quantities' in planning/realization process which indicates that if possible the quantities should be centralized into one source.	2	1	2	1

Appendix L: Implementation Plan for the New MKI-process

Het doel van dit implementatieplan is het beschrijven van het MKI-proces en hoe de implementatie ervan kan plaatsvinden binnen Mobilis TBI. In dit document worden de wie, wat, wanneer en hoe van de implementatie van het nieuwe MKI-proces uitgelegd.

Doel van het Proces en de Implementatie

Het proces, voortkomend uit het onderzoek, is ontwikkeld met als doel de integratie van de MKI-berekening en ondersteunende stappen te verbeteren voor alle Mobilis TBI-projecten. Dit moest bereikt worden door het proces te standaardiseren, controleerbaar te maken en duidelijk de taken en verantwoordelijkheden voor alle betrokken medewerkers aan te geven. Het uiteindelijke doel van dit proces is om bij te dragen aan de bedrijfsdoelen, namelijk het verminderen van fouten, het vergroten van bewustwording van milieueffecten en het verbeteren van duurzaamheidsinspanningen binnen de projecten van het bedrijf. Na afronding van het proces moet de implementatie plaatsvinden, waarbij het doel is om ervoor te zorgen dat het proces standaard wordt gebruikt, controleerbaar is en dat alle taken door de juiste verantwoordelijkheden correct worden uitgevoerd. Dit implementatieplan beschrijft verder hoe dit gerealiseerd kan worden.

Het Ontwerpproces van het Vernieuwde MKI Proces

Aan de hand van interviews en discussiegroepen met experts binnen Mobilis TBI is een gestructureerd proces afgerond. Hierbij zijn de problemen met het oorspronkelijke MKI-proces geïdentificeerd en vertaald naar oplossingen die zijn geïmplementeerd in het vernieuwde MKI-proces. Voor meer informatie over het ontwerpproces van het vernieuwde MKI-proces kan het onderzoeksrapport worden geraadpleegd.

Het vernieuwde MKI-proces is ontworpen door gebruik te maken van de ontwerpprincipes en ontwerpeigenschappen van een systematisch ontwerpproces genaamd ‘Design Science’. Bij het ontwerpen van het nieuwe MKI-proces is de beslissing genomen om twee afzonderlijke processen te creëren in plaats van één enkel proces, zoals het geval was in het oorspronkelijke proces. Deze keuze komt voort uit de erkenning dat een MKI-berekening voor de tenderfase aanzienlijk verschillende acties en een andere volgorde van deze acties vereist in vergelijking met het proces dat gebruikt kan worden tijdens de planning en uitvoeringsfasen van een project. Het maken van twee afzonderlijke processen zorgt ervoor dat de specifieke behoeften en overwegingen van elke fase effectief worden aangepakt. Het eerste proces, genaamd 'Opzetten MKI-berekening', kan worden gebruikt tijdens de aanbestedingsfase van een project. Het doel van dit proces is het opzetten van de MKI-waarde die benodigd is voor de aanbieding aan de klant om de impact van de werkzaamheden te verminderen. Het tweede proces, 'Bewaken MKI-berekening', kan vervolgens worden toegepast tijdens de planning en realisatiefases van een project. Het doel van dit proces is het bewaken van de opgestelde MKI-waarde tijdens de aanbesteding, die nu contractueel is opgelegd aan het project.

GEÏDENTIFICEERDE PROBLEMEN, OPLOSSINGEN EN EXTRA INFORMATIE

In deze Sectie zijn alle problemen die tijdens het onderzoek geïdentificeerd zijn, en de daarbij behorende oplossing toegelicht. Daarnaast is deze Sectie voorzien met extra informatie met betrekking tot de implementatie van deze oplossingen. De volgorde van de problemen is in dit implementatieplan opgenomen in de volgorde dat de oplossingen geïntegreerd zijn in het vernieuwde MKI-proces. Hierbij wordt uitgelegd hoe dit proces helpt deze problemen aan te pakken. In de subtitels staat eerst de geïntegreerde oplossing getoond met daarachter het geïdentificeerde probleem waarvoor deze oplossing in het leven is geroepen.

Procesflow en RASCI → Onduidelijke verantwoordelijkheid en overdracht

Met betrekking tot de taken binnen het bestaande MKI-proces was er verwarring over wie de verantwoordelijkheid had met betrekking tot bepaalde taken, vooral bij het achterhalen van materiaalhoeveelheden en de berekening zelf. Dit werd gezien als een aanzienlijk probleem en om deze reden zijn er twee nieuwe processen gecreëerd om deze onduidelijkheid te verhelpen. Als oplossing om deze onduidelijkheid te verhelpen is dit onderzoek uitgevoerd. Dit proces volgt de Sensus methodologie dat wordt gebruikt voor alle processen binnen Mobilis TBI. Op basis van de bevindingen uit de databronnen van dit onderzoek is er gekeken wat de juiste volgorde voor de taken is, wie daarvoor verantwoordelijk is en hoe deze overgedragen moet worden. Dit staat allemaal beschreven in beide vernieuwde processen. Voor enkele acties is extra informatie beschikbaar welke beschreven staat in dit implementatieplan bij de icoon van toepassing op deze extra informatie. De verantwoordelijkheden en ondersteunende rollen kunnen worden aangepast indien nodig. Als er aanwijzingen zijn dat een andere verdeling van taken en ondersteuning beter zou werken voor een specifiek project, moet hierover een overleg plaatsvinden en moeten de aanpassingen duidelijk worden vastgelegd in het project specifieke proces.

MKI-doelstelling Mobilis → Onduidelijkheid milieudoelstellingen Mobilis TBI

Binnen Mobilis TBI is er een noodzaak voor heldere MKI-doelstellingen voor alle projecten, gezien de cruciale rol van duurzaamheid. Overwegingen om MKI-beoordelingen uit te voeren voor alle projecten, vereisen interne doelen voor efficiëntie. Deze interne doelstellingen waren niet opgenomen in het oorspronkelijke MKI-proces. Echter, zonder deze doelstellingen is het berekenen van de MKI niet benodigd en kan de extra inspanning als overbodig voelen. Om deze reden werd als doelstelling uitgesproken dat het nieuwe proces voorzien moet zijn van een mogelijkheid om interne doelstellingen in het nieuwe MKI-proces op te nemen. Deze doelstelling is uiteindelijk uitgevoerd aan de hand van het toevoegen van een inputdocument voor zowel het initiatieproces als het planning- en realisatieproces waarin de MKI-doelstellingen vanuit Mobilis TBI meegenomen kunnen worden.

Voor de implementatie van de oplossing voor dit probleem zijn twee aspecten van belang. Allereerst, de Tendermanager of Projectmanager zijn aansprakelijk en de integraal ontwerpleider welke verantwoordelijk is voor het definiëren of controleren van de projectscope, afhankelijk van in welke projectfase het project zich momenteel bevindt. Deze moeten goed kijken of de directie van Mobilis project specifieke doelen heeft opgesteld voor het project. Als het gaat om de directie die doelstellingen vaststelt voor projecten, is het belangrijk om zorgvuldig te overwegen of deze doelen daadwerkelijk waarde toevoegen en niet te moeilijk zijn om te bereiken. In eerste instantie moet gedacht worden aan doelen die de MKI-waarde van hoge impact materialen zoals staal en beton onder een bepaald maximum houden om MKI-waarde over het hele project te verlagen.

Bepalen/Controleren correctheid MKI-scope → Variabiliteit van de scope in projecten
Bij Mobilis TBI-projecten leidt variabiliteit in de projectomvang, vaak door klantvereisten, tot onduidelijkheden en belemmert het de consistente MKI-beoordelingen. Om dit probleem op te lossen is als doel gesteld voor het nieuwe proces dat deze de mogelijkheid biedt om de scope duidelijk te bepalen rekening houdend met de mogelijke variabiliteit tussen projecten. Dit probleem is aangepakt door een extra actie toe te voegen aan het begin van beide processen. In het proces 'opzetten MKI-waarde' is een actie toegevoegd welke de scope bepaald en vervolgens in het proces 'bewaken MKI-waarde' een actie om te controleren of de eerder bepaalde scope nog steeds accuraat is. Deze acties zijn toegevoegd om het bepalen van de scope nauwkeuriger te maken. Projectmedewerkers moeten zich bewust zijn van de variaties in scope tussen verschillende projecten en niet zomaar de scope van een ander project overnemen. Wanneer nieuwe projectmedewerkers zich aansluiten bij het project, wordt de MKI-scope duidelijk gecommuniceerd om voor alle betrokkenen helder te maken wat wel en niet binnen de MKI-scope valt. Dit helpt onduidelijkheden te voorkomen en mogelijke fouten in de berekening van de MKI voor het project te vermijden.

Onduidelijkheden in aanbesteding/contracteisen? → Beperkte nadruk van de klant op milieueffecten
De klant legt vaak weinig nadruk op milieueffecten. Ondanks de vaak aangevraagde MKI-berekeningen, beïnvloeden prijsafwegingen nog steeds de besluitvorming, wat kostenefficiëntie boven milieuduurzaamheid plaatst. Daarnaast staan er in diverse gevallen tegenstrijdige eisen en wensen in het contract met betrekking tot duurzaamheid. Voor het vernieuwde proces is om die reden het doel uitgesproken om te zorgen dat het nieuwe proces voorziet in een moment om met de klant mogelijke onduidelijkheden of tegenstrijdigheden te bespreken. Dit doel heeft vorm gekregen in het nieuwe proces door een keuzemoment in beide processen waarin gekeken moet worden of er onduidelijkheden zijn in de tender of het contract. Mocht dit het geval zijn dan volgt in het initiatie proces een actie waarin een verzoek tot nota van inlichting gedaan wordt bij de klant en in het planning/realisatie proces een actie om in overleg te gaan met de klant. Om de duurzaamheidsaspecten van Mobilis TBI te tonen is het van belang om initiatief te tonen en eventuele duurzamere oplossingen of mogelijkheden met de klant bespreekbaar te maken. Hiernaast is het ook van belang om te blijven vernieuwen om tot deze duurzamere oplossingen en mogelijkheden te komen.

Bepalen/actualiseren ontwerphoeveelheden → Gebrek aan een enkele bron voor materiaalhoeveelheden in aanbesteding
Bij Mobilis TBI ontbreekt momenteel een enkele bron voor materiaalhoeveelheden in aanbestedingen, wat leidt tot verschillen in de bepaalde materiaalhoeveelheden door het gebruik van verschillende tools. Het doel is om een betrouwbare bron te hebben om handmatige invoer te verminderen en fouten te voorkomen. Technische uitdagingen en complexiteit van bouwmaterialen vormen echter obstakels. Vanwege technische beperkingen is het momenteel niet mogelijk om dit op een standaard wijze door te voeren in het proces en moet er om die reden rekening gehouden worden met de aard van het project en de projectfase.

Als doel voor dit proces is gesteld dat het voorzien moet worden van een enkele bron voor het bepalen en actualiseren van ontwerphoeveelheden. De ideale situatie is dat materiaalhoeveelheden worden verzameld in BIM en hieruit wordt direct de MKI-waarde getrokken. Voor deze situatie is echter verder onderzoek vereist hoe deze situatie gecreëerd kan worden met de capaciteiten en technische mogelijkheden binnen de BIM-omgevingen van Mobilis TBI. Op dit moment is de meest ideale situatie dat voor alle projecten waar BIM gebruikt wordt, de materiaalhoeveelheden uit BIM getrokken worden naar een Excel bestand. Deze materiaalhoeveelheden kunnen dan vervolgens aangevuld worden met behulp van de calculator en werkvoorbereiding en vervolgens vermenigvuldigd met de MKI-waarde van de materialen om tot de MKI-waarde van het project te komen. Voor vroege schattingen is het niet mogelijk om BIM te gebruiken dus voor de initiatie fase wordt het aangeraden om schattingen te maken voor de materiaalhoeveelheden door de werkvoorbereiding en deze vervolgens steeds verder te concretiseren. Vervolgens kan overgegaan worden op gebruik van het 3D model wanneer dit in gebruik is. In deze situatie wordt de belangrijkste support rol gedurende het project overgedragen van werkvoorbereiding naar modeleur. Wanneer er bij een project geen 3D model in gebruik is, is het aan te raden om de materiaalhoeveelheden te achterhalen bij de calculator. Deze heeft voor de calculatie ook de volledige materiaalhoeveelheden benodigd. Echter is deze oplossing niet ideaal aangezien calculators druk zijn op het moment van indiening wanneer ook de MKI-berekening bepaald moet worden.

LCA-bibliotheek → Gebrek aan bewustzijn over het bestaan van een LCA-bibliotheek
Mobilis TBI mist bewustzijn over het bestaan van een LCA-bibliotheek en hoe deze te gebruiken. Uit de interviews die zijn uitgevoerd voor het onderzoek bleek dat verschillende medewerkers binnen Mobilis TBI niet op de hoogte waren van het bestaan van een dergelijke LCA-bibliotheek, en daardoor ook niet wisten hoe deze te gebruiken. Als doel voor dit nieuwe proces is gesteld dat in dit vernieuwde proces duidelijk moet zijn hoe deze LCA-bibliotheek is te gebruiken en waar deze te vinden is. Dit is uitgevoerd door in beide nieuwe processen een actie toe te voegen waarin een impact analyse wordt uitgevoerd en voor de materialen met een hoge impact kan een waarde uit de LCA-bibliotheek gebruikt worden. Om aan te geven dat deze LCA-bibliotheek bestaat is een input gemaakt voor deze bibliotheek in beide processen. Het is daarnaast belangrijk om te weten dat de duurzaamheidscoördinator altijd verantwoordelijk is voor het gebruik van de LCA-bibliotheek. De redenen hiervoor zijn dat de duurzaamheidscoördinator op de hoogte is van welke LCA-waardes geldig zijn in deze bibliotheek en kunnen worden gebruikt voor een specifieke situatie. Het moet namelijk een MKI-waarde zijn voor het juiste materiaal en voor de juiste berekeningsmethode. Aangezien deze methode door de jaren heen meerdere keren is gewijzigd, kan een LCA-waarde op een gegeven moment ongeldig worden.

Controleren definitieve hoeveelheden → Gebrek aan gestructureerde controle van hoeveelheden
Binnen het MKI-proces ontbreekt een gestructureerde aanpak voor het controleren van materiaalhoeveelheden, wat de nauwkeurigheid van milieu-impactbeoordelingen en kostenschattingen beïnvloedt. Tijdens een van de focusgroepen werd opgemerkt dat tijdens een aanbesteding het voorkomt dat er met verschillende bronnen van hoeveelheid wordt gewerkt, vanwege het hoge tempo waarin gewerkt moet worden tijdens zo'n aanbesteding. Dit kan leiden tot situaties waarbij bij de indiening blijkt dat verschillende berekeningen zijn gemaakt met diverse hoeveelheden, wat kan leiden tot fouten. Om dit aan te pakken, is er een stap toegevoegd na het voltooien van de berekening in het proces 'opzetten MKI-waarde'. Hierbij wordt gecontroleerd of alle gebruikte hoeveelheden in verschillende berekeningen, zoals bijvoorbeeld de calculatie, overeenkomen.

Mocht er consequent een enkele bron komen in de toekomst voor het verzamelen van materiaalhoeveelheden, dan zou deze stap overbodig geacht kunnen worden. Echter kan de bron voor materiaalhoeveelheden over tijd heen ook verschillen wanneer op een laat moment een andere ontwerpoplossing gemaakt zou worden. Daarom wordt het aangeraden op dat moment deze actie in het proces te behouden.

Bepalen kansen en risico's MKI → Ongestructureerd gebruik van de bandbreedtebepaling
In Mobilis TBI projecten vormt de ongestructureerde benadering van bandbreedtebepaling een uitdaging, vooral in de beginfase waar initiële MKI-waarden vaak geschat worden door een gebrek

aan details. Het behouden van een gestructureerde bandbreedte is essentieel om onzekerheden te beheersen, financiële boetes te voorkomen en opgelegde milieudoelen te bereiken. In het oude proces was de bandbreedtebepaling die over de MKI-waarde van het project werd getrokken als risico mitigatie als een van de eerste dingen geschrapt om tot een scherpere inschrijving te komen. Dit is echter een groot risico. Om deze reden werd voor dit proces als doel gesteld dat er een aspect in het proces moest komen waar de risico's werden beoordeeld met betrekking tot de MKI en de bepaalde bandbreedte ook daadwerkelijk te gebruiken en niet te schrappen. Laat de specifieke risicobeperkende maatregelen niet achterwege, omdat deze met een reden zijn vastgesteld.

Contractwijzigingsproces → Gebrek aan standaard controle van de MKI bij VTW's

Mobilis TBI staat momenteel voor een aanzienlijke uitdaging met betrekking tot het ontbreken van een gestandaardiseerde controle voor het beheren van de implicaties van MKI tijdens contractuele wijzigingen. Het probleem komt aan het licht wanneer aanpassingen aan het contract worden geïnitieerd en de gevolgen van de MKI niet consequent worden aangepakt en gecontroleerd. Als doel is gesteld om een controle element toe te voegen bij een VTW met betrekking tot de MKI. Er is besloten dat deze toegevoegd zal moeten worden in het contractwijziging proces door een extra indicatie toe te voegen dat de verandering aan het contract geanalyseerd moet worden met betrekking tot de verandering aan de MKI-waarde op het project. Het is van belang dat bij elke VTW wordt gekeken wat de invloed is van de VTW op de MKI-waarde. In veel gevallen zijn dit punten die gratis meegenomen kunnen worden in het project. Mocht deze niet meegenomen worden is het namelijk moeilijker om de eerder vastgestelde MKI-waarde te behalen.

Onvoldoende kennis en ervaring met MKI

Mobilis TBI kampt met een gebrek aan kennis en ervaring in het MKI-proces, wat de volledige benutting van MKI in projectmanagement belemmert. Aangezien het gebruik van MKI relatief nieuw is zijn er nog niet veel projectmedewerkers die bij meer dan één project in aanraking zijn geweest met de MKI. Om deze reden is het lastig om kennis en ervaring met de MKI op te bouwen. Wel zijn er MKI-trainingen geweest die als goed werden ervaren door de medewerkers. Echter is er in het proces geen toevoeging gedaan met betrekking tot dit probleem op aanraden van experts tijdens het onderzoek.

Enkele aanbevelingen op basis van dit onderzoek met betrekking tot dit probleem zijn dat de MKI-trainingen die op het moment worden gegeven, gegeven moeten blijven worden en mogelijk moeten worden aangepast op het vernieuwde MKI-proces. Daarnaast is het belangrijk om medewerkers meer betrokken te houden met MKI om bewustzijn te verhogen. Veel medewerkers gaven aan dat een Kick-off MKI-meeting aan het begin van een tender of project voor hen veel toegevoegde waarde zou hebben. Door het continue toe passen van de interne MKI-doelstelling zullen meer projecten werken met de MKI waardoor medewerkers sneller ervaring en kennis opbouwen met betrekking tot de MKI.

Gebrek aan projectgericht werken met betrekking tot de MKI

Projectteams missen een duidelijke focus op projectgerichtheid bij MKI-aspecten. Gebrek aan projectgerichte focus leidt tot inefficiëntie en gemiste kansen. Doordat de scope tussen projecten varieert is er geen uniforme oplossing. Tijdens de focusgroepen van het onderzoek is er besloten dat het geen toegevoegde waarde heeft om extra acties of documenten toe te voegen aan het proces om dit probleem te verhelpen. Echter zijn er wel aspecten binnen dit proces die aandacht nodig hebben met betrekking tot dit probleem. Zoals gezegd verschilt de MKI-scope tussen projecten sterk. Om deze reden is gebleken dat het lastig is geweest voor projectteams om projectgericht te werken. In het vernieuwde proces moet aandacht besteed worden aan het duidelijk bepalen en controleren van de scope en deze goed communiceren met het projectteam.

Risico's bij de Implementatie van het Vernieuwde MKI-Proces

In deze sectie van het implementatieplan worden enkele risico's besproken die zijn geïdentificeerd tijdens het onderzoek en waarmee rekening moet worden gehouden bij de implementatie van het vernieuwde MKI-proces.

Overslaan van stappen in het proces:
Het risico bestaat dat projectteamleden stappen in het proces overslaan, vooral stappen die zijn toegevoegd naar aanleiding van de probleemidentificatie. Deze nieuwe stappen, zoals de bepaling van de scope, controle van hoeveelheden aan het einde van het aanbestedingsproces en het evalueren van MKI-impact bij een VTW, zijn nieuw voor projectteamleden en kunnen daarom potentieel overgeslagen worden. Het niet uitvoeren van deze stappen kan de effectiviteit van het vernieuwde proces verminderen.

Niet volgen van verantwoordelijkheden:
Medewerkers kunnen terugvallen op oude gewoontes en verantwoordelijkheden overslaan of vermijden, waardoor de beoogde standaardisatie en controleerbaarheid in gevaar komen.

Weerstand binnen het projectteam:
Het vernieuwde proces kan weerstand binnen het team veroorzaken, vooral als medewerkers niet betrokken zijn geweest bij het ontwerpproces. Dit kan de acceptatie en implementatie belemmeren.

Onvoldoende training en communicatie:
Als de training en communicatie over het vernieuwde MKI-proces niet voldoende zijn, kan dit leiden tot verwarring en foutief gebruik door medewerkers die mogelijk niet op de hoogte zijn van het bestaan of de werking van het vernieuwde MKI-proces.

Gebrek aan enkele bron voor materiaalhoeveelheidverzameling:
Op dit moment is het nog niet mogelijk om alle hoeveelheden te verzamelen in één enkele bron. Wanneer dit wel mogelijk wordt, kan de efficiëntie van het MKI-proces worden verhoogd.

Onvolledige integratie met bestaande processen:
Als het vernieuwde MKI-proces niet naadloos integreert met bestaande processen, kunnen er efficiëntieproblemen ontstaan.

TAKEN, VERANTWOORDELIJKHEDEN EN PLANNING IMPLEMENTEREN MKI-PROCES

In deze Sectie staan de vervolgstappen voor het implementeren van het nieuwe MKI-proces. Idealiter worden deze stappen op volgorde uitgevoerd tijdens de implementatie van het nieuwe proces.

1. Koppelen van het MKI-proces aan bestaande processen in Prosizer:

Taak: Het integreren van het vernieuwde MKI-proces met de bestaande processen in Prosizer.
Extra informatie: In de twee processen staan een aantal koppelingen met al reeds bestaande processen. Voordat het vernieuwde proces gebruikt kan worden moeten eerst deze koppelingen kloppend in Prosizer worden gezet.
Verantwoordelijk: Proces engineer

2. Voorzien van informatie aan gebruikers:

Taak: Voorzien in een informatiesessie voor de tender- en projectteams die het vernieuwde MKI-proces gaan gebruiken.
Extra informatie: Voor de uitvoering van een aanbesteding en een project is het van belang dat het tenderteam en projectteam bekend zijn met het gebruik van de MKI en informatie krijgen over de veranderingen van het proces en wat hun rol hierin is.
Verantwoordelijk: Duurzaamheidscoördinator

3. Uitvoeren van een aanbesteding en een project met het nieuwe proces:

Taak: Het uitvoeren van een aanbesteding en een project gebruikmakend van het vernieuwde MKI-Proces.
Verantwoordelijk: Tender- en Projectmanager

4. Evaluatie gebruik van vernieuwd MKI-proces:

Taak: Het evalueren of het vernieuwde MKI-proces.
Extra informatie: Na het gebruik van het nieuwe MKI-proces is het van belang om te evalueren of het nieuwe proces effectief en efficiënt zijn doel heeft bereikt.
Verantwoordelijkheid: Duurzaamheidscoördinator

5. Onderzoeken en verhelpen van eventuele tekortkomingen van het nieuwe proces:

Taak: Identificeer en analyseer eventuele tekortkomingen in het nieuwe proces en neem corrigerende maatregelen.
Verantwoordelijkheid: Duurzaamheidscoördinator/ Onderzoek

6. Vaststellen doelstellingen vanuit Mobilis TBI met betrekking tot de MKI:

Taak: Vaststellen van de doelstellingen die vanuit Mobilis TBI komen waar projecten aan moeten gaan voldoen tijdens realisatie van de projecten.
Extra informatie: In het nieuwe proces is een input gemaakt waarin de doelstellingen vanuit Mobilis TBI zijn beschreven, zodat de doelstellingen voor een project gewaarborgd kunnen worden. Echter moeten deze doelstellingen nog vastgesteld worden door de directie.
Verantwoordelijkheid: Directie

7. Onderzoeken en implementeren materiaalhoeveelheidverzameling in enkele bron:

Taak: Onderzoek mogelijkheden voor materiaalhoeveelheidverzameling in een enkele bron en implementeer een geschikt systeem.
Extra informatie: Een van de geïdentificeerde problemen die niet is verholpen met de creatie van het nieuwe MKI-proces is het verzamelen van de materiaalhoeveelheden in een enkele bron. Bij geslaagde implementatie van het nieuwe MKI-proces kan er onderzocht worden om dit probleem op een andere wijze op te lossen.
Verantwoordelijkheid: Duurzaamheidscoördinator/ Onderzoek