SUSTAINABILITY OF CONSTRUCTION PROJECTS

An effective evaluation framework with a reporting method based on performance indicators within the context of the Triple Bottom Line

Ioannis Kiziridis

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Colophon

Master thesis

University	Delft University of Technology
Faculty	Civil Engineering and Geosciences (CiTG)
Master program	MSc. Construction Management and Engineering (CME)

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Preface

This master thesis was carried out as a partial fulfillment of the MSc Construction Management and Engineering (CME) at Delft University of Technology. The research was completed during the period May 2020-January 2021. This nine month period was filled with a lot of hard work but also plenty of learning experiences which have equipped me with a deeper understanding of the concept of sustainability at its core.

Coming to the end of this trip and achieving the desired outcome, would not have been possible without the guidance and support of some people. For this reason, I would like to thank my graduation committee members. I would like to express my gratitude to the chairman of my graduation committee, Henk Jonkers, for critically monitoring the research and for all the key feedbacks he gave me. I would also like to thank my supervisors, Xinju Liu and Daan Schraven, for providing me with time, support and guidance. Their constructive comments and the motivating discussions I had with them made me reflect on different aspects of the problem. Last but not least, I would like to thank professor Marcel Hertogh, for acting as the committee chairman up until the kick-off meeting but due to exceptional circumstances, our further collaboration was not made possible.

Moreover, I would like to thank all those involved in the case study and made it possible as it was a critical step in this research. More specifically, I would like to express my gratitude to the employees from Dura Vermeer for providing all the relevant information for the studied project as well as their personal views and opinions as sustainability experts.

Lastly, a large part of this research was carried out during the pandemic of COVID-19 where everyone's life was turned upside down and socializing had become extremely restricted. Thus, I feel the need to recognize the moral support of my family and friends who kept me motivated during the challenging times of the pandemic and provided me with joyful distractions when it was necessary. These people played the most important role in this process although most of them are completely irrelevant with the research topic.

Ioannis Kiziridis

Delft, January 2021

EXECUTIVE SUMMARY

Introduction

John Elkington coined the phrase Triple Bottom Line (TBL) in 1994 in order to introduce social and environmental considerations in the traditional finance-centric measurement system of business performance. As a tool to measure sustainability performance, the three bottom lines refer to the environmental, social and economic aspects of sustainability respectively. Sustainable construction has been defined as the delivery of environmental-friendly, socially acceptable and economically profitable projects, where the three pillars of sustainability are balanced in an optimal manner. The implementation of the TBL framework in the construction sector is considered to be insufficient due to the industry's reluctance to change. The objective of this research is to create an assessment tool based on performance indicators that will encourage construction companies to continuously monitor and improve sustainability performance. This study aims to answer the following research question: **How can sustainability integration into construction projects be structured such that it leads to quantitative performance reporting on all three dimensions of the Triple Bottom Line?** This study employs a mixture of qualitative and quantitative research where systematic literature review and case study research are used in order to achieve the research objectives.

Research approach

Initially, a literature review is conducted to investigate the current state of TBL in the construction industry and identify existing assessment frameworks and performance indicators. Although there is an increase in research trends and studies pertaining to the TBL in the construction industry, the holistic evaluation of TBL implementation has not been researched sufficiently. A total number of 71 indicators were identified (24 for environment, 24 for society and 23 for economy, respectively). Thirteen assessment frameworks are studied of which the 9 were developed by scholars for the construction sector while the remaining 4 concern other industries. The need for the development of a new assessment tool derives from the disadvantages of these frameworks, i.e. they focus on a single dimension of the TBL or they provide qualitative assessments. Furthermore, the renowned assessment tools of LEED, BREEAM and GPR are studied as they are widely used and can add value to the process of developing the new assessment method.

The next step refers to the development of the assessment tool. Firstly, the final sets of indicators need to be defined. The filtering process consists of two stages. During the first stage, the initial inventory of indicators is reviewed content-wise. Indicators with similar content are merged while sector-specific indicators are excluded. In the second stage, the remaining indicators are filtered according to the variety of sources in which an indicator appears into (triangulation) and the frequency of appearance in literature. The final sets consist of 14 indicators for the environment, 15 for the society and 13 for the economy.

Then, the procedure for the calculation of weights for the indicators is provided. This method does not predefine the weighting factors as these differ from project to project. The calculation of weights for every indicator is done according to the views and interests of the project stakeholders. They are asked to rate the importance of each indicator on a scale from 1 to 5 and the weights are calculated with the statistical measure of Relative Importance Index (RII).

In order to assess the performance of a project on the given indicators, a scoring system is introduced. The project performance is assessed on a scale from 1 to 5, where 1 stands for extremely bad performance and 5 for exceptional performance. The method suggests that, for the scoring, different assessments by external consultants should be performed and obtain the average score.

The assessment score for each indicator is calculated by multiplying the average performance score with the weight and the assessment scores are summed for every dimension of sustainability. At this point, the minimum (if all indicators were scored as 1), maximum (if all indicators were scored as 5) and sufficient (if all indicators were scored as 3) assessment scores are also calculated to allow for comparison with the assessment score achieved. Lastly, the results are plotted in spider diagrams to allow decision makers to focus on specific indicators and propose actions to improve performance.

In the following stage, the case study is utilized and the purpose is twofold: On the one hand to investigate the current practices applied in the field of sustainability and, on the other hand to examine the feasibility of applying the proposed tool. The selected case is an infrastructure project in the Netherlands, currently in its early construction phase and construction works are temporary on hold due to opposition from environmental groups. The investigation of current practice showed that sustainability assessment in the studied project is carried out in terms of CO_2 emissions while the societal and economic aspects are addressed through the company's corporate responsibility and management system but they are not treated as dimensions of sustainability. Therefore, the implementation of the TBL framework is rather vague.

As far as the applicability of the proposed tool is concerned, the possibility for the company to incorporate the proposed tool in its processes is quite low for the main reasons of limited availability of resources and that it does not constitute a client requirement. However, the importance of the aspects covered by the indicators is acknowledged, the assessment procedure is considered as simple and straightforward and the results could be very easily communicated with the interested stakeholders.

The case study revealed some weaknesses of the proposed assessment method and it is attempted to improve these shortcomings through adaptations to the method. The most important deficiency was ambiguity and subjectivity in judgements. For that reason, a hybrid approach regarding evaluation criteria is proposed in order to differentiate evidence-based with non-evidence based assessment. The evaluation criteria suggested for evidence-based assessments are 1) standards and minimum requirements and 2) comparison with similar projects. Obviously, evidence-based assessment is preferred if the necessary data is available as this type of assessment includes reduced subjectivity. In the absence of available data to justify the assessment, the questionnaire survey and expert's judgement are introduced as secondary evaluation criteria in order to ensure that all important sustainability aspects are included in the assessment procedure.

Moreover, a conceptual framework that includes the assessment methodology is proposed to help organizations adopt the assessment tool in their daily practices. Simplicity is main principle used for the design of the framework and it is intended to stimulate regular interaction with the project's stakeholders and commitment for continuous monitoring and improvement.

Conclusion and discussion

The case study confirmed the poor integration of the TBL framework in the construction industry and the need for governmental regulation to enhance implementation is highlighted. The main research question is answered with the proposal of the conceptual framework that enhances the integration of sustainability into construction projects throughout the entire life cycle by connecting sustainability performance with the views and interests of the affected stakeholders. The assessment methodology produces quantified results which are easy to communicate with the relevant parties.

The practical contribution of this research is that it raises awareness of the TBL framework in the construction industry and provides construction companies with an assessment tool to help them adopt TBL principles in their reporting philosophy which in turn could turn out to be a competitive advantage in the market. Scientifically, this research helps to fill the research gap in literature regarding holistic evaluations of the TBL framework in the construction industry. The matter of subjectivity in the assessment process constitutes a serious limitation in the research as it could not be addressed adequately due to the qualitative nature of the proposed indicators.

Lastly, the author recommends future research topics in order to enrich the previous results. The exploration of the interrelation of the proposed indicators, the execution of a cost-benefit analysis on the adoption of the conceptual framework as well as the development of standardized evaluation rubrics that respect diverse lines of evidence could be of added value to the current research.

Table of contents

List of Figures

List of tables

List of Abbreviations

Abbreviation	In words
CE	Circular Economy
DBFM	Design, Build, Finance and Maintain
ECI	Environmental Cost Indicator
EMAT	Economically Most Advantageous Tender
GDP	Gross Domestic Product
KPI	Key Performance Indicators
SD	Sustainable Development
SDGs	Sustainable Developments Goals
SKAO	Foundation for Climate Friendly Procurement and Business
TBL	Triple Bottom Line
UN	United Nations

1. RESEARCH CONTEXT

1.1 Introduction to research topic

The climate change and its implications have been observed for decades now. The first (almost) universally adopted action took place in 1987, in Montreal (The Montreal Protocol, n.d.) where all member states of the United Nations (UN) ratified to limit the production and consumption of man-made chemicals that deplete the ozone layer. Today, the Paris Agreement (United Nations, 2015) on keeping the global temperature rise for this century below 2 degrees Celsius is the most recent agreement between countries aiming at fighting climate change. Based on the aforementioned, the notion of Sustainable Development (SD) emerged from the need to mitigate human intervention into the environment. SD has been defined in many ways but the most commonly quoted definition comes from the Brundtland Report (United Nations General Assembly, 1987, para. 27):

"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Along with the population growth and rise of living standards across the globe, comes a growing demand for buildings and infrastructures. The construction industry is considered as a vital element of a country's economy, playing a key role in society well-being (Zhang et al., 2019). Being one of the most energy- and carbon-intensive industries, the construction sector is characterized by high energy consumption, thus producing more than one third of global carbon dioxide emissions (Zhang & Wang, 2004; Son et al., 2011). The before mentioned result in a great pressure for the international construction industry to limit CO_2 emissions and slow down global temperature rise (Zhang et al., 2019). This pressure is also depicted in the UN agenda for 2030, in some of the 17 Sustainable Development Goals (SDGs). For instance, building resilient infrastructure (Goal 9) and responsible consumption and production (Goal 12) are two characteristic examples that are directly connected and affect the construction industry (United Nations Sustainable Development Goals, n.d.)

One step further to the definition of SD, Kibbert (1994) introduced the term "sustainable construction" as "the creation and responsible management of a healthy built environment based on resource efficient and ecological principles". An up-to-date statement on this term comes from Goh et al. (2019) who support that "sustainable construction must ensure the delivery of environmental, social and economic sustainability in a balanced and optimal manner, without one pillar dominating any others". The definition from Goh et al. (2019) treats sustainability in construction as a multidimensional issue. The concept of Triple Bottom Line (TBL) was first introduced by John Elkington in 1994 and evolved to help achieve the goal of sustainable development (Goh et al., 2019). As a tool to measure sustainability performance, TBL refers to social, environmental and economic sustainability. The societal dimension measures community well-being, health and safety, public engagement, equality and diversity (Goh, 2017) while environmental sustainability refers to the harmony between nature and buildings (Sjostrom & Bakens, 1999). Lastly, economic sustainability in construction concerns the financial gains that a project provide to its stakeholders (Abidin, 2010). According to Liu et al. (2019) and based on the TBL principle, true sustainability can be achieved in the overlap of all three dimensions, as depicted in Figure 1.

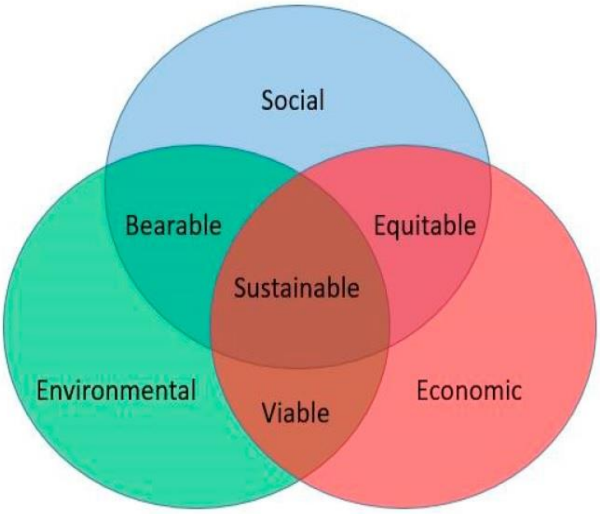

Figure 1.1 The Three Dimensions of Sustainability (Liu et al., 2019)

1.2 Problem statement

1.2.1 Practical problem

The TBL framework was initially used as an accounting framework that attempted to consider the social and environmental aspects in the traditional finance-centric measurement system of business performance (Elkington, 1994). The framework can also be found in the literature as the 3Ps: people, planet and profits (Slaper & Hall, 2011). Although the TBL framework seems to have been successfully adopted in many industries, the implementation in the construction sector is rather vague. The construction industry is characterized by a "reluctance to change" and this statement is attributed to many factors such as insufficient collaboration between suppliers and contractors, absence of skilled workforce and insufficient knowledge transfer among projects (World Economic Forum, 2016). Slapper and Hall (2011) state that there is no standardized assessment method to evaluate performance on all three dimensions of TBL while Schulz and Flanigan (2016) claim that quantification and evaluation of the three dimensions of TBL and especially the social and environmental dimension is a challenging task. In addition, Liu et al. (2019) state that research trends have focused on developing assessment methods for the end result of sustainability. Thus, the aforementioned led to the formulation of the problem that this research will attempt to solve, and that is the absence of a robust framework for sustainability integration into construction projects with a clear performance assessment method and enough flexibility to be applied in different kinds of projects.

1.2.2 Research gap

Although the number of articles pertaining to TBL in the construction industry has increased in the recent years, no prior research has been conducted to holistically evaluate the TBL implementation in construction practices (Goh et al., 2019). For instance, some articles focused solely on the barriers of implementation in specific countries (Ametepey, Aigbavboa, & Ansah, 2015; Opoku & Ahmed, 2014), others proposed frameworks for implementation (du Plessis, 2007) and assessment or measurement methodologies to support integration (Kucukvar & Tatari, 2013). Some attempts have also been made to provide assessment frameworks (Karji et al., 2019). However, they were focused on a single dimension of TBL only. In other industries, Govindan, Khodaverdi and Jafarian (2012) developed a multi criteria approach to measure sustainability performance of a supplier based on the TBL approach, while Tyrrell, Paris and Biaett (2012) developed a quantified TBL approach for tourism.

1.3 Research objective

The main objective of this study is to develop a sustainability performance assessment method that adheres to the concept of TBL, where the three pillars of sustainability contribute equally to the final outcome. The methodology is intended for construction enterprises to raise awareness on the TBL framework and to perceive sustainability as a multidimensional concept and promote a new philosophy of reporting results.

1.4 Research question and sub-questions

According to Goh et al. (2019), sustainable construction refers to the delivery of environmentally friendly, socially acceptable and economically efficient projects without any dimension dominating the others. Even though the original intention of TBL was to provide holistic assessments of sustainability, there is no standardized method on reporting results (Slaper & Hall, 2011). Hill and Bowen (1997), support that the absence of a standardized reporting method to evaluate performance on the three pillars of sustainability hampers the proliferation of innovative solutions. Hence, the central research question is formulated as follows:

How can sustainability integration into construction projects be structured such that it leads to quantitative performance reporting on all three dimensions of the Triple Bottom Line?

In order to guide the main research question and enhance the probability of providing a clear answer in the end, a set of four sub-questions have been determined. The formulation of the following sub-questions has been made in such a way that the combined answers of those questions will supply the researcher with adequate information to answer the central question they derive from (Verschuren & Doorewaard, 2010). Hence, the sub-questions that will steer the research are:

1. What are the performance indicators and existing frameworks for sustainability assessment within the context of TBL in the construction industry?
2. How can we select an appropriate set of indicators that covers adequately the three dimensions of TBL and how can these indicators be utilized to create an assessment methodology?
3. To what extent is the proposed methodology applicable in the construction industry and how flexible it is to be applied in different types of projects?
4. How to make a new framework that could lead to enhanced integration of construction sustainability and reduce subjectivity in the assessment procedure?

The first sub-question aims to explore the current state of research in the area of construction sustainability in order to understand the root causes of poor sustainability integration in construction processes. For that purpose, existing frameworks and structured approaches will be researched.

The second sub-question deals with the methodological approach that will be followed to select an appropriate set of indicators that represent equally the three pillars of sustainability. The answer that this question seeks for will lay the foundation for the development of an assessment methodology to enhance the implementation of sustainable construction practices.

The next question has been formulated to evaluate the possible implications of this research in the overall area of sustainability in the construction industry. It questions the practicality of the proposed framework and the degree of universal application.

The last question pertains to the end-product that this research intends to provide. As Taylor and Fletcher (2006) mention, any new framework has to be simple and practical, flexible and adaptive, including specific examples of application and taking into account the fact that practitioners have little time and limited funds and expertise to run the assessment process.

1.5 Research design

The first stage of this study will focus on identifying performance indicators and existing assessment tools in field of sustainability in the construction industry. Initially, the large scientific database Scopus will be utilised in order to acquire an in-depth knowledge in TBL framework and track the indicators identified so far. To extract a sufficient number of sources, the survey will employ the keywords "triple bottom line", "sustainab*","construction". In order to observe how the TBL framework has evolved over time, the literature survey will foucs on papers published from 1994 ,when its was first introduced (Elkington, 1994), and later.

The following phase of the research refers to the selection process of the indicators that will form the final set. A wide variety of indicators have already been developed for the construction industry and other sectors as well. The indicators identified during the literature review will be refined according to certain criteria and the final sets will be determined. Furthermore, the selected indicators will be structured into an assessment methodology and the calculation procedure will be elaborated.

After developing the tool, the feasibility of applying it to a real-life project needs to be investigated. For this purpose, the case-study method is utilised. The reason behind the choice of this method lies in the following criteria (Yin, 2003, p. 5):

- The type of research question and subquestions
- The control of the researcher over and access to behavioral events, and
- The degree of focus on contemporary phenomena

The application is also expected to shed some light in the current practices applied by the industry when it comes to reporting sustainability results. During this stage, qualitative interviewing will take place to receive feedback on the proposed methodology which will be used for validation purposes. This type of interview provides the interviewees with flexibility and the interviewer can continue with follow up questions on the answers provided (Bryman, 2012). Furthermore, for the above mentioned reasons and in order to acquire a wide range of information, the design of the interview questions will be based on the following principles (Turner, 2010, pp. 757-758):

- Use open-ended questions
- Avoid leading questions
- Probe issues in depth

- Let the informant lead

In the next step, possible adjustments to the assessment methodology will be incorporated, based on the findings from the case study. In addition, a conceptual framework that encompasses the assessment method will be proposed. The intention of the framework will be to enhance sustainability integration into construction projects and motivate construction enterprises to continuously improve sustainability performance through effective monitoring and targeted intervention.

The last but crucial step will be to summarize the results and examine if the research questions are answered adequately. Moreover, the possible implications of this research will be discussed and recommendations for future research will be provided.

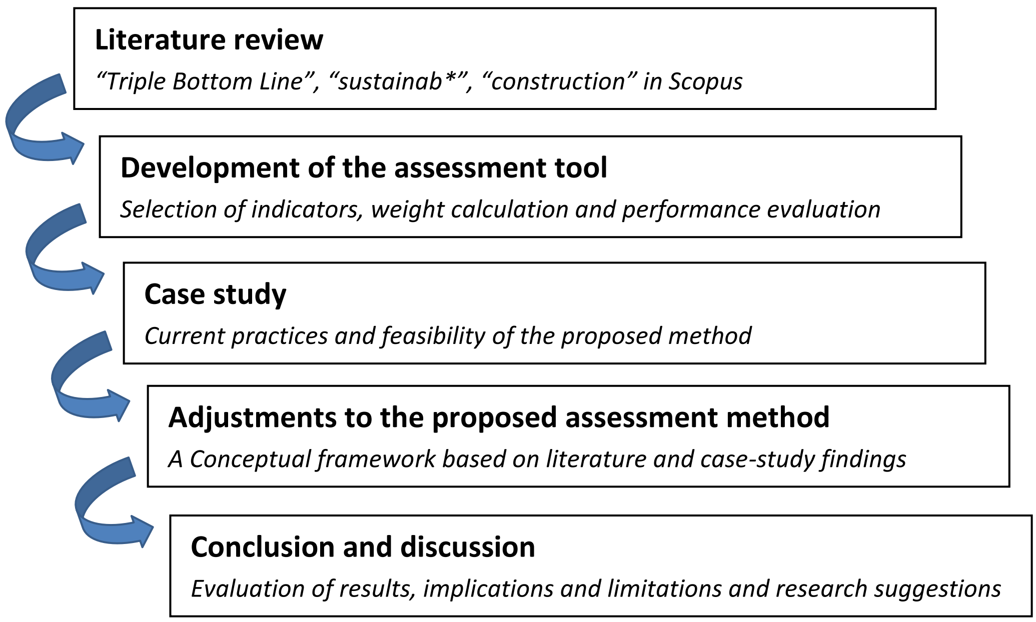

Figure 1.2 Research design visualization (own illustration)

1.6 Thesis structure

This section describes the structure of the research and results in the outline presented in Table 1.1.

The introductory part addresses the wider context, the problem formulation, the current research gap and the main research question accompanied with the sub-questions. Chapter 2 presents the state-of-the-art literature review while chapter t3 presents the methodological approach that will be followed in order to meet the research objectives. Chapter 4 contains the identification of performance indicators and the analysis of the existing assessment frameworks. The next chapter in line contains the development of the method which takes into account the findings from the previous chapters. The assessment methodology is followed by a case-study application in chapter 6 in order to evaluate the appropriateness of the tool and compare it with current practices. In chapter 7, the proposed methodology is revised and a conceptual framework is proposed. The last chapter discusses the results of this study, provides the answers to research questions and designates contribution, limitations and future research suggestions. The very last section of this report will be devoted on providing the full list of references from the works that have been used for writing this thesis.

Table 1.1 Thesis outline

Chapter 1	Research context
Chapter 2	Literature review
Chapter 3	Methodological approach
Chapter 4	Performance indicators and assessment frameworks
Chapter 5	Developing the assessment methodology
Chapter 6	Case-study
Chapter 7	Revised assessment method and proposal of a conceptual framework
Chapter 8	Conclusion, discussion and recommendations
References	

2. LITERATURE REVIEW

2.1 Sustainable Development and Sustainable Construction

SD is an evolving concept with international debate around its meaning. However, the general consensus is that SD is the process of rearranging the relationship between human needs and the environment, with positive impact for both current and future generations and sufficient variety in opinions about which approaches should be followed, priorities to be set and drivers to steer the process (du Plessis, 2005). It has already been mentioned before that sustainability is spread across three axis. Tamak (2017) provides alternative definitions of sustainability; the societal dimension refers to fair and beneficial business practices across the community and the region where an organization operates. The environmental aspect pertains to the maximum utilization of the natural capital while minimizing harm and environmental impact on the surrounding ecosystem. Lastly, economic prosperity relates to an equitable long term economic development.

The construction sector contributes to the socio-economic development by providing the infrastructure and productive facilities, contributing to the Gross Domestic Product (GDP) and providing direct employment to millions of people worldwide (Ofori, 2007). Apart from the definition given by Charles Kibert in 1994, sustainable construction has also been defined as a combination of processes and products which is directed in minimizing the use of energy and harmful emissions and provides relevant information to customers for decision-making purposes (Huovila and Richter, 1997, cited in du Plessis, 2005). Other definitions describe sustainable construction as “a way of building which aims at reducing (negative) health and environmental impacts caused by the construction process or by buildings or by the built environment” (Lanting, 1998, p. 7) or as “the use and/or promotion of a) environmentally friendly materials, b) energy efficiency in buildings, and c) management of construction and demolition waste (UNEP, 2003, cited in du Plessis, 2005, pp. 407-408).

It is more than clear that the above definitions are merely focused on the environmental aspect. Hence, sustainability was initially perceived as environmental protection and preservation. The societal and economic dimensions were later integrated to provide a more holistic definition (Abidin, 2009).

2.2 Current state of TBL

John Elkington first coined the term of TBL in 1994. He now claims that the time has come for a “strategic recall” on the concept as the evaluation of sustainability strategies and options, on the basis of real-world impact, has failed (Elkington, 2018).

A study conducted by Goh et al. (2019) found that the number of articles on TBL pertaining to the construction sector has increased to 5-10 articles per year for the period 2009-2017 comparing to 1-3 articles per year in 1996-2005. This finding shows a significant increase in research trends and studies conducted to address the concept of TBL within the concept of sustainable construction. However, these studies approached the idea of sustainability from different angles.

2.2.1 Awareness of sustainable construction

A number of studies aimed to investigate the level of awareness in the construction industry. In Malaysia, Abidin (2010) examined the level of knowledge and implementation of sustainable construction practices due to complaints about the poor environmental performance of projects. It was found that only large developers concerned sustainability issues for their projects and most developers restrain from pursuing sustainability in their projects as a result of knowledge deficit and cost concerns. Yin et al. (2018) investigated the perceptions of sustainability in construction practices and policies among big contractors through an extensive questionnaire. The results showed that, on the one hand, contractors would respect and adhere to government regulations but, on the other hand, respondents were not eager to undertake initiatives for new practices. Thus, effective changes could only be driven by governmental regulations. AlSanad (2015) presents the lack of awareness as the main reason for low sustainable construction practices and highlights the need for more action and strategies.

2.2.2 Barriers of implementation

Other researches focused on the barriers for implementation of sustainable construction practices. It is argued that critical stakeholders ask for a sustainable built environment however, those involved in the delivery of construction projects are confronted with many challenges. In the light of this, Opoku and Ahmed (2014) conducted a research to identify the main challenges that organizations are faced with, when attempting to adopt sustainable practices. High capital cost was identified as the most challenging issue among others such as lack of common understanding, absence of client demand and kills of employees. Ametepey, Aigbavboa and Ansah (2015) attempted to identify and rank the possible barriers to sustainable construction in Ghana and they found that factors such as cultural change resistance, lack of government commitment, fear of high investment costs and lack of knowledge and legislation, hinder the successful implementation of construction sustainability measures. Again, governmental regulation is suggested as the indicated measure to overcome the barriers and make sustainable construction more competitive. Generally, governmental action through legislative frameworks was found in a number of studies (Ametepey, Aigbavboa, & Ansah, 2015; Manoliadis, Tsolas, & Nakou, 2006; Serpell, Kort, & Vera, 2013) to be the main driver for the enhancement of sustainability. On top of governments' role, involved stakeholders could play a crucial role in implementation efforts across the construction industry (Majdalani, Ajam, & Mezher, 2006) .

2.2.3 Approaches to help integrate sustainability in construction processes

In the light of challenges and drivers identified in earlier studies, a plethora of researches have suggested frameworks and strategies to pave the way for an industry-wide successful adoption of sustainable principles. Du Plessis (2005) proposed a two-dimensional framework for sustainability integration in Africa's construction industry. The first part refers to the establishment of a knowledge foundation while the second part is related with the creation of an agency that would steer the process. In the same line, Sev (2009) proposed a conceptual framework that follows a life-cycle approach to enhance sustainability implementation where the principles of resource management, life-cycle design and design for human and environment are integrated. For each one of the three principles, strategies and methods to be followed are presented. In addition, Sev (2009) stressed the importance of holistic application and the need to set priorities in decision making according to local conditions. Goh et al. (2019) integrated life-cycle thinking with the three pillars of sustainability to provide a framework that supports the adoption of sustainability principles in the future. Green assessment and policy making could help sustain the environment, a collaborative platform engaging all project stakeholders would result in better alignment of their expectations and lifecycle costing is essential to shift the focus from initial costs to the long-term benefits of involved stakeholders.

It is argued that the construction industry should have a long-term vision to ensure that the sector will be developed in a sustainable manner and an efficient implementation framework with explicit legal procedures and public consultation processes is indispensable (Wong, Ng, & Chan, 2010). For that reason, Wong, Ng and Chan (2010, pp. 259-262) suggested four strategic directions to help achieve sustainable development: (i) adapting long-term vision and policy, (ii) creating favorable factor conditions and resources, (iii) cultivating a best practice culture and (iv) enhancing technical competency.

With regards to stakeholder engagement, Bal et al. (2013) found that it is essential for the project team to follow six crucial steps in order to ensure stakeholder engagement: (i) key-stakeholders identification, (ii) connect stakeholders with specific sustainability targets, (iii) stakeholders prioritization, (iv) stakeholder management, (v) performance measurement, and (vi) transform objectives into actions. Holloway and Parrish (2015) argue that contractors should be involved in the process of developing of sustainability goals for projects from early stages. The early engagement of contractors in the design process could help understand their stand

and incentives for participation, as well as their expertise would provide alternative solutions to overcome specific barriers.

2.3 Existing assessment frameworks

Numerous sustainability assessment frameworks exist that have been developed in order to help practitioners measure progress in attaining sustainability targets. However, these frameworks present major differences in terms of assessment type, level of detail and adherence to the TBL principles.

As far as the construction industry is concerned, evaluation frameworks based on life cycle thinking have been proposed by different scholars (Goh, 2017; Dong & Ng, 2016; Zhang et al., 2014) while other researchers developed assessment frameworks based on performance indicators (Preasley & Meade, 2010; Karji et al., 2019; Lundin & Morrison, 2002). Apart from the construction sector, assessment frameworks have been proposed other industries as well. Tyrrell, Paris & Biaett (2012) proposed integrated framework for quantitatively assessing sustainability performance in tourism while Govindan, Khodaverdi & Jafarian (2012) developed a multi criteria approach for evaluating sustainability performance in the supply chain industry based on TBL principles. Junior, Oliveira & Helleno (2018) integrate the three dimensions of TBL with the four perspectives of the Balance Score Card to assess sustainability in the manufacturing industry. For process engineering systems, Mangili, Santos & Prata (2019) proposed an extensive assessment methodology based on weighted performance indicators.

In practice, rating schemes have been developed by private organizations that are widely used to rate sustainability performance of construction projects. In this research, the rating systems of LEED, BREEAM and GPR were chosen to be further investigated. These rating schemes use different point-systems for various sustainability areas of projects and, in the end, they provide sustainability certificates according to the achieved performance.

A more thorough analysis of the existing assessment frameworks and methodologies follows in section 4.2.

3. METHODOLOGICAL APPROACH

3.1 Introduction

This chapter is devoted to present the methodological approach that will be followed to meet the objectives of this research. This study follows a mixed approach of qualitative and quantitative research and is structured in two parts. Part 1 refers to the theoretical background on sustainable development and the TBL framework while the second part designates the methodological steps that are followed in order to develop the new assessment tool.

The research approach is visualized in figure 3.1 and a thorough elaboration on the sub-parts is given in the following sections. It is important to note that this research is not carried out in strict chronological order, as figure 3.1 illustrates. In fact, the case study reveals unexplored aspects of sustainability assessment in practice and the literature is enriched with additional studies, where appropriate. However, this research scheme constitutes a fundamental point of reference that will allow the reader to comprehend the sequence of this study.

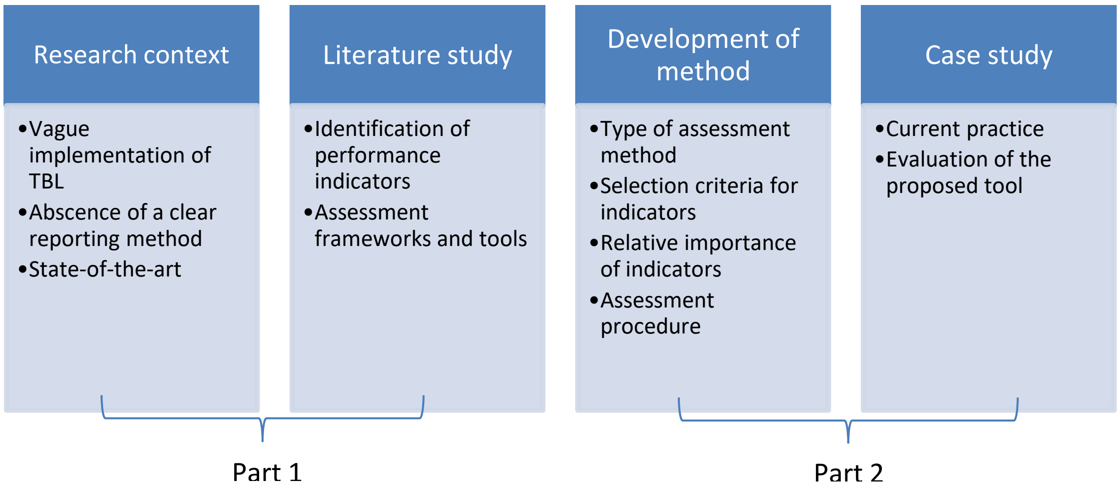

Figure 3.1 Research approach (own illustration)

3.2 Part 1 - Theoretical background

The research is initiated by presenting and analyzing the existing problem. The vague implementation of the TBL framework in the construction industry is highlighted. Moreover, the absence of a clear reporting method on the basis of the TBL was found to hinder the adoption of sustainable construction practices.

A thorough literature study follows in order to gain a deep insight of the TBL framework. The large scientific database Scopus is utilized and with the use of “triple bottom line”, “sustainab*” and “construction” as keywords, an initial pool of scientific papers is created. These papers are reviewed in terms of content and relevance with the research objectives. The literature is also enriched with the widely used sustainability rating schemes of LEED, BREEAM and GPR so as to investigate the sustainability assessment from a practical point of view. The output of this phase is an inventory of performance indicators for all three aspects of TBL as well as an inventory of sustainability assessment frameworks and schemes.

3.3 Part 2 – Development of the new assessment tool

In this section, the methodological steps to develop the assessment method are designated. This part consists of the development of the sustainability assessment methodology and the execution of a case study with a dual scope: to test the theory from the literature review and examine the applicability of the proposed tool. Obviously the development of such an assessment tool may turn out to be an iterative procedure where multiple iterations between development and testing are needed. However, for the scope of this research and due to time limitations, the investigation of the applicability of the proposed tool will be examined only once and the observations from the case study will be used to propose further improvements to the assessment methodology.

3.3.1 Type of assessment

Several sustainability assessment frameworks and tools have been developed by numerous scholars that adhere to the TBL principles. According to Mangili, Santos & Prata (2019), these evaluation techniques can be grouped in three main categories: Indicator-based frameworks, Life cycle assessments and Eco-efficiency approaches. A short description of each assessment type along with their respective advantages and disadvantages is given below in order to provide a rationale for the selection of the assessment method that will be used in this research.

<u>Indicator-based frameworks:</u>

Performance indicators are metrics that can be used to measure target attainment and provide an insight on areas of improvement (Fereira, Rizo, & Lopez, 2018). A set of performance indicators constitutes a valuable decision-making instrument if the indicators represent sufficiently the system under consideration (Fereira, Rizo, & Lopez, 2018). Key performance indicators can be used to evaluate the performance of a specific activity, sector or even an entire organization within the context of TBL (Mangili, Santos & Prata, 2019).

Advantages:

-Quantified end result (Mangili, Santos & Prata, 2019);

-Targeted improvement (Mangili, Santos & Prata, 2019);

-Simple and transparent information to assist decision making (Mangili, Santos & Prata, 2019);

-Easy communication with stakeholders (Goh, 2017)

Disadvantages (Mangili, Santos & Prata, 2019):

-Some aspects are particularly difficult to measure;

-Disclosure of confidential information may be needed

<u>Life cycle assessment</u>

Life Cycle Sustainability Assessment (LCSA) is an integrated approach consisting of the three life cycle techniques: Environmental Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Social Life Cycle Assessment (S-LCA) (Dong & Ng, 2016). The assessment output can be calculated with the formula provided by UNEP/SETAC (2011) as:

$$LCSA = LCA + LCC + S\text{-}LCA$$

Advantages (UNEP/SETAC, 2011, p. 3):

-LCSA enables practitioners to organize environmental, economic and social data in a structured way;

-LCSA helps clarify the trade-offs between the three sustainability dimensions;

-LCSA allows organizations to consider the full impact of their operations;

-LCSA raises awareness in value chain actors on sustainability issues;

-LCSA helps identify weaknesses;

-LCSA stimulates innovation in companies and value chain actors

Disadvantages (Mangili, Santos & Prata, 2019):

-Quite complex frameworks;

-Uncertainties regarding quality of data;

-A substantial amount of data may not be available on time

-Time consuming

Eco-efficiency approaches

By definition, eco-efficiency is defined as the ratio of benefits to their associated environmental impacts (Mangili, Santos & Prata, 2019).

Advantages (Mangili, Santos & Prata, 2019):

-Joint evaluation of performance metrics;

-Quantified results;

-Simplicity;

-Can be used to compare different product systems

Disadvantages (Mangili, Santos & Prata, 2019):

-Eco-efficiency approaches usually do not provide a single value as the evaluation outcome;

-Focuses solely in reducing material input

The different methods for assessing the sustainability performance have been analyzed before and the conclusion is that there is not a particular assessment method to be considered as the "holy grave" for evaluating sustainability performance. Each assessment type has its benefits and drawbacks and the selection of the assessment system needs to be made according to the objectives and the purpose of the application. The objective of this research is to create an assessment tool from the contractor viewpoint, that takes into account the needs and interests of the participating stakeholders. Almahmoud & Doloi (2015) support that by integrating the stakeholder's interests in the assessment procedure, the chances of achieving sustainable development targets are increased.

Taylor & Fletcher (2006) claim that an assessment framework needs to be simple and practical; be flexible enough to be used in small and large projects; and take into account that practitioners have limited time to run the assessment process. In addition, the proposed assessment tool will seek for interaction with the project's stakeholders. Based on the abovementioned, the choice has been made to select an indicator-based assessment method as a more appropriate tool to meet the objectives of this research.

3.3.2 Selection of indicators

The filtering process for the final sets of indicators is carried out in two stages.

<u>Stage 1:</u>

During the first stage, the initial inventory of indicators is reviewed in terms of content. Some indicators appear to be more general while others exist as sub-category of an all-encompassing indicator. Such indicators will be merged with others with relevant content. Moreover, indicators that refer exclusively to a specific type of construction projects will be removed.

<u>Stage 2:</u>

For the second filtering stage, the selection will be based on the two criteria presented below. The general rule will be that if an indicator satisfies at least one of the following criteria, it will be included in the final set.

-Variety of sources: The use of multiple data sources in research is called triangulation and is used to validate the research findings (Heale & Forbes, 2013). This criterion suggests that an indicator appears in (at least two) different kind of sources (i.e. literature review, UN global indicator framework and Rating systems from private institutions)

-Frequency of appearance in literature: If an indicator appears frequently in the studied literature it means that the importance of that metric is acknowledged by different scholars. Hence, the frequency of an indicator appearing in the studied literature provides a sound reasoning for the importance of this indicator. The threshold for an indicator to satisfy this criterion will be set in at least three times in literature.

3.3.3 Relative Importance

After selecting an appropriate set of indicators to carry out the assessment procedure, the next issue that arises is the importance of indicators. In other words, should all indicators contribute equally to the final assessment outcome or is different weighting a more righteous choice? In case the latter is the preferred, the choice for a mechanism to calculate the weights needs to be justified.

Perceptions of sustainability vary among different stakeholders (Ametepey, Aigbavboa & Ansah, 2015; Karji et al., 2019). Various stakeholders might even have conflicting views of sustainability. On top of that, the objective of this research is to create an assessment tool that is universally applicable to the overall construction industry and not restricted to a specific type of construction projects. A performance indicator that can be extremely important in an infrastructure project may be insignificant for a residential building and vice versa. For the above reasons, the application of different weighting factors when executing a sustainability performance assessment is chosen for the proposed tool.

It has already been stated that the assessment tool attempts to create a link between sustainability performance and stakeholders' interests. There are various methods to compute weights that are based in strict mathematical models and equations. Fu, Xu & Xue (2018) mention the methods of direct rating, point allocation, eigenvector, linear programming and goal programming as ways to assign weights to attributes. In this research, the statistical tool of Relative Importance Index (RII) will be used to create a ranking between indicators based on the stakeholders' interests and allocate weights to the indicators that will affect the assessment outcome. This choice was based on the fact that the RII is an easy-to-use tool and the results can be easily communicated with the affected stakeholders.

3.3.4 Case study research

According to Yin (2003, p. 5), there are several options when conducting social science research and each method has specific advantages and disadvantages. The most common research strategies are: Experiment, Survey, Archival analysis, History and Case study (Yin, 2003, p. 5). The choice for an appropriate research method is based on the following considerations: a) the type of research question, b) the researcher's control over behavioral events and c) the degree of focus on contemporary phenomena (Yin, 2003, p. 5).

At first, the main research question is a "how" question. Secondly, the researcher has little or no control of behavioral events meaning that the relevant behaviors cannot be manipulated. Lastly, this research focuses on contemporary phenomena meaning that direct observation of the events being studied can be achieved and interviews with the people involved in the events can be conducted.

Based on the above considerations, Yin (2003, p. 5) suggests that the case study is preferred as a research strategy since "a "how" question is being asked about a contemporary set of events, over which the researcher has little or no control".

Once the choice has been made for the case study as a research method, the next question refers to the number of case studies to be conducted. Yin (2003) suggests that a single case study can be used to confirm, challenge or extend a well-formulated theory. A second rationale to use a single case study is when the case is considered as a unique case. The results from the systematic literature review constitute a well-formulated theory and due to the fact that the researcher has limited access to real-life projects, conducting a single case study for this research deems appropriate.

For the selection of a suitable case, the following two criteria will be used:

- The project needs to be in its early construction phase: This criterion would ensure that the project adheres to the latest available sustainability standards and access to people involved in the project would be easier.
- The project should have relatively complex sustainability requirements: This criterion satisfies the second condition mentioned before that a single case needs to represent the unique case. Otherwise, if an “average” project was to be selected, multiple cases would be needed to verify the theory.

4.PERFORMANCE INDICATORS AND ASSESSMENT FRAMEWORKS

4.1 Identification of performance indicators

4.1.1 Inventory of indicators from research papers

Indicators are representative measures that can describe the state of a system of changes within a system (Anon, 2006b, cited in Hakkinen, 2007). By deploying indicators, complex phenomena are described simply and communicated easier among different parties (Hakkinen, 2007). Mangili, Santos and Prata (2019) argue that with the help of Key Performance Indicators (KPIs), various aspects of an activity, sector and an entire organization can be assessed. KPIs can add value to decision-making processes as they provide understandable and transparent information. However, the selection of a suitable indicator set constitutes a significant problem (Fernandez-Sanchez & Rodriguez-Lopez, 2010). The indicators identified for the three dimensions of sustainability and help measure sustainability performance in the construction industry, are presented in the tables below (the full tables with the references are provided in Appendix A):

Table 4.1 Environmental sustainability indicators

	Environmental sustainability indicators	**Number of studies**
1	Adaptation and vulnerability to climate change-environment	3
2	Air quallity around the project	3
3	Application on energy saving,ecology and intelligent technology	2
4	CO2 uptake land	1
5	Deforestation	1
6	Disaster risks (quakes/floods)	1
7	Ecosystem/Biodiversity protection	9
8	Energy performance/Energy consumption	9
9	Greenhouse gas emissions	8
10	Indoor environmental quality	3
11	Land use	2
12	Loss of habitat	1
13	Material resources/ sustainable use of natural resources	8
14	Material circularity	2
15	Noise level/reduction	5
16	Pollution	2
17	Protection of water resources	2
18	Recycling of materials and water	4
19	Renewable energy	7
20	Site selection	1
21	Use of green products	2
22	Waste management	6
23	Water and waste water efficiency strategies	3
24	Water footprint	5

Table 4.2 Social sustainability indicators

	Social sustainability indicators	Number of studies
1	Aesthetics/visual impact	2
2	Culture and heritage preservation	2
3	Fair sharing of benefits	1
4	Gender equality	1
5	Health, comfort and well being of occupants	6
6	Wages and benefits	3
7	Influence on the local economy	2
8	Leisure	1
9	Living environment/ Needs assessment of society-people	3
10	Local participation	5
11	Local social development	1
12	Local workforce	2
13	Market supply and demand	1
14	Occupational health and safety	6
15	Peace and justice	2
16	Percentage of community residents who must be relocated due to the project/community disturbance	1
17	Productivity	1
18	Reducing inequalities	2
19	Safety and security	2
20	Taxes	2
21	Transportation infrastructure/accessibility and amenities	3
22	Use of regional materials	2
23	User and owner satisfaction	3
24	Work created throughout the project cycle	3

Table 4.3 Economic sustainability indicators

	Economic sustainability indicators	Number of studies
1	Abbility to pay and affordability	3
2	Business ethics	3
3	Contribution to GDP	3
4	Cost management plan	6
5	Design and Construction time	1
6	Developing an efficient risk management plan	6
7	Economic and political stability	2
8	Economic diversity in project affected areas	1
9	Effective change management strategy	3
10	Effective project control	5
11	Efficient allocation of resources	4
12	Financial performance	5
13	Flexibility	1
14	Gross Operating Surplus	1
15	Imports	1

16	Innovation management/new product development	7
17	Integrated management	1
18	Investment amount	3
19	Life/endurance of construction and design	2
20	Percentage of population receiving external benefits in project affected areas	1
21	Project output emphasis	1
22	Readjustment for new business environment	1
23	Supply chain collaboration	1

4.1.2 The UN global indicator framework

One of the criteria used to refine the initial set of indicators is the UN global indicator framework (IAEG-SDGs, 2017). The idea is to compare the indicators identified during the literature study with the sustainability goals and targets set by the UN for the so-called 2030 Sustainable Development Agenda. According to the UN, this is a 15-year plan to stimulate action in areas of critical importance for humanity and the planet. Namely, these areas are: People, Planet, Prosperity, Peace and Partnership (IAEG-SDGs, 2017). The first three areas correspond to the TBL framework also known as the 3P's. The agenda is mutually agreed and universally adopted by country members, therefore providing the critical areas of attention within the context of SD. Thus, this framework can serve as a reliable criterion for the selection of an appropriate set of indicators.

In order to enhance the implementation and the monitoring process, 169 targets have been set and 231 unique indicators have been developed by the Inter-Agency and Expert group on SDG Indicators (IAEG-SDGs) (IAEG-SDGs, 2017) to measure progress towards sustainable development. The 17 Goals are presented in figure 4.1.

The analytical tables with the results from the comparison with the UN targets can be found in Appendix B.

Figure 4.1 The 17 Sustainable Development Goals by the UN (United Nations Sustainable Development Goals, n.d.)

4.2 Analysis of existing assessment frameworks

4.2.1 Construction industry

In this section of the report, existing assessment frameworks focused on the construction industry will be discussed. These are either sector specific (e.g. housing construction) or generally applicable to any type of construction project. Furthermore, these methods vary in level of detail, type of assessment (quantitative, qualitative) and the degree of coverage on the three dimensions of the TBL. The frameworks mentioned below were identified and studied during the literature review and will serve as a basis for the development of a new, integrated approach.

The Cooperative Research Centre for Catchment Hydrology (the CRC) of Australia has developed assessment guidelines to evaluate the impact of urban stormwater projects within the context of TBL (Taylor, 2005). This is a 12-step approach where qualitative values are transformed into measurable scores by deploying an impact matrix and experts' judgement. These guidelines employ multi criteria analysis in order to support decision making and allow assessors to choose between three levels of assessment depending on the magnitude, complexity and potential impact of the project.

Goh (2017) support that an integrated assessment of the TBL could play a pivotal role in the implementation of macro-level policies as the unification of the three dimensions would have greater value than the sum of the dimensions individually. Based on life cycle thinking, Goh (2017) proposes an integrated approach that recognizes the interdependencies between social, environmental and economic aspects and allows for quantification of the TBL elements. His approach is based on four main principles: 1) define goal and scope; 2) determine spatial and temporal scales; 3) develop an extensive database with supportive information; 4) identify sustainability indicators. In the same line, Dong and Ng (2016) developed a modeling framework for sustainability assessment of construction based on life cycle thinking. Their model combines three life cycle techniques, namely the environmental life cycle assessment (LCA), life cycle costing (LCC), and social life cycle assessment (S-LCA). The final assessment outcome derives from the sum of the life cycle assessments for each dimension of sustainability, i.e., environment, economy and society.

Presley and Meade (2010), borrowed from LEED the indicators pertaining to the environmental aspect of the TBL and supplemented them with economic and social indicators to provide a benchmarking framework for construction enterprises. After applying weights on indicators, a score for each indicator is calculated and then all scores are summed to provide a total score for the specific firm. This framework is useful for construction companies that wish to identify their position in the market or, in other words, how does a company compare with its competitors. Zhang et al. (2014) proposed a prototype system dynamic model to evaluate sustainability performance of construction projects. According to their model, a construction project is assessed for the contribution it has on the sustainable development, throughout its life cycle.

A number of studies aimed at providing evaluation methodologies and frameworks for a single dimension of the TBL only. Karji et al. (2019) claim that the social dimension of sustainability has received less appreciation within the context of TBL. Therefore, they developed a four-step approach to evaluate social sustainability in mass housing construction. Their approach consists of (1) selecting sustainability rating systems to be examined, (2) identifying the Social Sustainability Key Assessment Indicators (SSKAI), (3) ranking and weight computation of SSKAIs and (4) calculating the score of Social Sustainability for a given project. Almahmoud and Doloi (2015), support that social sustainability is well served when the multiple interests of a project's stakeholders are being met. Their model integrates social network analysis and seven "social core functions" to dynamically evaluate the degree to which the stakes of the stakeholders are satisfied. A dynamic model deemed appropriate as the stakeholders and their relative stakes evolve throughout the project's lifecycle.

Regarding the environmental aspect of sustainability, a research carried out in the UAE to measure building performance showed that economic development resulted in intense construction activities which, in some cases, disregarded the effect on the environment (AboulNaga & Elsheshtawy, 2001). AboulNaga and Elsheshtawy (2001) created an assessment tool to evaluate building environmental sustainability performance in terms of energy use and CO_2 emission. According to this model, energy saving measures such as natural ventilation, solar heating and free cooling are assessed on a scale from 0 (not important) to 7 (very important) and the final outcome of the assessment is the Building Energy Efficiency which is the ratio of Energy Requirement to Energy Consumption. Lundin and Morrison (2002) propose a structured and iterative procedure to select Environmental Sustainability Indicators (ESI) based on life cycle assessment (LCA). This iterative approach gives space alterations in the set of ESI through case studies and LCAs. Finally, the assessment results in four levels of environmental sustainability, ranging from A to D, where Level A refers to clean urban water infrastructure and Level D is the last and worst rating where the infrastructure does not meet the minimum standards for environmental protection and human health.

Table 4.4 Assessment frameworks for the construction industry

Framework	Type	Environmental	Social	Economic
AboulNaga & Elsheshtawy (2001)	Quantitative	√		
Almahmoud & Doloi (2015)	Quantitative		√	
Dong & Ng (2016)	Quantitative	√	√	√
Goh (2017)	Qualitative	√	√	√
Karji et al. (2019)	Quantitative		√	
Lundin & Morrison (2002)	Qualitative	√		
Presley & Meade (2010)	Quantitative	√	√	√
Taylor (2005)	Quantitative	√	√	√
Zhang et al. (2014)	Quantitative	√	√	√

4.2.2 Private institutions

Along with the increased awareness for sustainable development, a number of organizations emerged who provide the so-called sustainability certifications. This part of the report presents and analyses three renowned organizations and their assessment tools.

LEED (U.S. Green Building Council, n.d.)

The acronym LEED stands for Leadership in Energy and Environmental Design (U.S. Green Building Council, n.d.) and is a green building rating system provided by the U.S. Green Building Council. A specific rating system is provided depending on the nature of the project. In more detail, a certification could be given for Building Design and Construction (BD+C), Interior Design and Construction (ID+C), Operations and Maintenance (O+M), Neighborhood Development (ND), Homes and Cities and Communities. Assessment is carried out according to a scoring system where points are given based on sustainability features in certain areas and the ranking is given in four levels : Certified (40-49 points), Silver (50-59 points), Gold (60-79 points) and Platinum (80-110 points). The sustainability areas and examples of features are given in the table below:

Table 4.5 Sustainability sections and issues according to LEED (U.S. Green Building Council, n.d.)

Sustainability section	Assessment issues
Location and Transportation (max points: 16)	-Surrounding density and diverse uses -Sensitive land protection
Sustainable Sites	-Protect or Restore habitat

(max points: 10)	-Rainwater management
Water Efficiency (max points: 11)	-Indoor water use reduction -Outdoor water use reduction
Energy and Atmosphere (max points: 33)	-Optimize energy performance -Renewable energy
Material and Resources (max points: 13)	-Building Life-Cycle impact reduction -Construction and Demolition waste management
Indoor Environmental Quality (max points: 16)	-Low-Emitting materials -Daylight
Innovation (max points: 6)	-Innovation -LEED Accredited Professional
Regional Priority (max points: 4)	-Specific credit

*the examples are taken from the Building Design and Construction (BD+C) category, for new construction

It can be concluded from the above that LEED focuses on environmental aspect of buildings to achieve its mission "to transform the way buildings and communities are designed, built and operated, enabling an environmentally and socially responsible, healthy and prosperous environment that improves quality of life" (U.S. Green Building Council, n.d.).

BREEAM (Building Research Establishment, n.d.)

The Building Research Establishment Environmental Assessment Method (BREEAM) is an evaluation method for masterplanning projects, infrastructure and buildings that assesses environmental, social and economic performance according to standards developed by BRE. Sustainability performance is examined throughout the whole lifecycle, from design and construction to refurbishment. Assessment is being done in ten categories where the most influential factors are addressed. Score points or credits are allocated by an external, certified assessor for each category and different weighting is applied. Once the assessment is complete, the weighted category scores are added to provide the final rating. The final rating is given in a series of stars, ranging from Acceptable (1 star) to Pass, Good, Very Good, Excellent and Outstanding (6 stars). Different standards have been developed by BRE to perform assessments for communities, infrastructure, new construction, in-use and refurbishment & fit-out. Below, the categories and examples of issues are presented in a table.

Table 4.6 Sustainability sections and issues according to BREEAM

Sustainability sections	Assessment issues
Management	-Life cycle cost and service life planning -Commissioning and handover
Health and wellbeing	-Indoor air quality

	-Visual comfort
Energy	-Reduction of energy use and carbon emissions -Energy efficient equipment
Transport	-Public transport accessibility -Proximity to amenities
Water	-Water consumption -Water leak detection
Resources	-Construction waste management -Circular economy
Resilience	-Exposure to climate change and other risks -Pro-active management of risks
Land use and ecology	-Site selection -Long term impact on biodiversity
Pollution	-NO_x emissions -Reduction of noise pollution

*The information is based on the BREEAM USA In-Use technical manual for residential buildings (Version 6.0.0)

GPR (W/E ADVISEURS, n.d.)

In the Netherlands, W/E consultants provide the GPR software, an online tool that claim to measure sustainability performance of buildings. The three dimensions of the TBL are addressed to a certain degree as the assessment is carried out in five themes.

-**Energy**: Focus is given on improving energy performance

-**Environment**: In this theme, the environmental impact of buildings is assessed.

-**Health**: Issues such as noise limitation, comfortable ventilation and sufficient fresh air and daylight are considered.

-**Quality of use**: The degree to which the specific needs of various target groups are being met to create a safe living environment.

-**Future value**: This section measures the future value of a building based on material waste and extra costs that would be needed in case of reconstruction or renovation.

Each sustainability theme is rated on a scale from 1 to 10 and the score for each theme is added to provide the final assessment outcome.

4.2.3 Other industries

Apart from the construction industry, sustainability is an evolving notion that has drawn massive attention in other sectors of the economy as well. A thorough review of methods developed for evaluating sustainable practices in other industries can provide a useful insight and ideas that could potentially, and with proper modifications, be implemented in the construction industry.

Tyrrell, Paris and Biaett (2012) attempted to overcome the challenge of integrating the three dimensions of TBL by developing a quantified model for sustainability evaluation in tourism. They highlight the importance of using a common measurement unit in order to assist decision-making. Thus, the environmental and societal dimensions are expressed in monetary units. For this method, ten sustainability attributes were selected in total (three for social and environmental, four for economic respectively) and different weights were applied according to individual preferences of respondents on a questionnaire survey. Scores for each attribute are then monetarized with help of coefficients. The outcome of the assessment process is a single number of tax dollars that an enterprise would contribute to the local community. An important limitation to mention here is that assessment for each attribute is only being done in two levels, namely high and low score.

Govindan, Khodaverdi & Jafarian, (2012) claim that sustainability is a multi criteria nature problem where subjectivity, uncertainty and vagueness are involved. In order to deal with these issues, they developed a multi criteria approach to assess sustainability performance of a supplier within the context of TBL in supply chain management. First, selection criteria are defined for the economic, environmental and social dimension. Then, the fuzzy sets theory is employed to rate criteria and allocate weights. Finally, the final ranking between suppliers is given by a multi attribute decision making technique called TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) (Govindan, Khodaverdi, & Jafarian, 2012). In this way, an order preference is created and the supplier with the best sustainability performance is selected according the judgement of decision makers.

In the manufacturing industry, a sustainability evaluation model was proposed by Junior, Oliveira and Helleno (2018) that associates the three dimensions of the TBL with the four perspectives (learning and growth, process, market and financial) of the Balance Score Card (BSC). For this reason, a 3x4 matrix was created from which 12 correlations derived. Every correlation was linked with an indicator and a “question to be answered” was formulated to allow performance evaluation. Through interviews with top managers of a firm, each indicator was assessed in a scale of 1-10 and the mode (most common value among given observations) was obtained. Finally, the scores on each indicator are plotted in a diagram which allows decision makers to focus on specific indicators and take actions when needed.

A number of sustainability evaluation models have been developed based on performance indicators as it is relatively easy to quantify and measure performance

(Mangili, Santos, & Prata, 2019). However, such methodologies rely heavily on qualitative data or fail to consider all perspectives in a holistic way. With this mentioned, Mangili, Santos and Prata (2019) proposed an extensive, systematic methodology that attempt to evaluate the overall sustainability performance of process engineering systems based on weighted performance indicators. Their approach consists of 8 steps. Especially for the calculation of weights, the authors support that these can be defined on either the assessor's expertise, company vision or specific objectives associated with that analysis (Mangili, Santos, & Prata, 2019). Since the idea of sustainability has a multi-criteria nature, the authors present an overview of Multi-Criteria Decision Making analysis methods. To name a few, the Weighted Sum Method (WSM), Weighted Product Method (WPM), Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) are some characteristic examples among others. The last step of the process in considered to be crucial as it refers to a sensitivity analysis. In this way, it can be assessed how the critical elements of the method influence the final outcome.

4.2.4 Commentary on existing frameworks

This part of the report aims to summarize and discuss the assessment frameworks that were identified during the literature review. Such action deems necessary as a critical evaluation of the existing frameworks could pave the way for the development of a new one, which combines the strengths and eliminates the weaknesses of the identified frameworks, to a certain degree. For better overview, advantages and disadvantages of each assessment methodology are shown in the following table:

Table 4.7 Critical review of existing frameworks

	Framework	**Advantages**	**Disadvantages**
Construction industry	*AboulNaga & Elsheshtawy (2001)*	Quantitative	Single dimension
	Almahmoud & Doloi (2015)	Quantitative	Single dimension
	Dong & Ng (2016)	Quantitative, Life cycle approach	O&M phase not included, interpretation of results
	Goh (2017)	Life cycle approach	Qualitative
	Karji et al. (2019)	Quantitative	Single dimension

	Lundin & Morrison (2002)	Life cycle approach	Single dimension, qualitative, sector specific (urban water systems)
	Presley & Meade (2010)	Quantitative	Assesses companies not projects
	Taylor (2005)	Quantitative	Time consuming, relies on expert judgement
	Zhang et al. (2014)	Quantitative	Complex
Private institutions	LEED (v4.1)	Quantitative, covers a large variety of projects	Focused mainly in Environment, Experts' judgement
	BREEAM (version 2016)	Quantitative, covers a large variety of projects	Focused mainly in Environment, Experts' judgement
	GPR	Quantitative	Focused mainly in Environment, Experts' judgement
Other industries	*Govindan, Khodaverdi & Jafarian (2012)*	Three dimensional, quantitative	Sector specific
	Junior, Oliveira and Helleno (2018)	Three dimensional, quantitative, simple	Sector specific
	Mangili, Santos, & Prata (2019)	Three dimensional, quantitative	Sector specific, complex, amount of data needed
	Tyrrell, Paris and Biaett (2012)	Three dimensional, quantitative	Assessment only in two levels: low and high

4.3 Key takeaways from identification of indicators and assessment frameworks

To summarize this chapter, the findings from the literature review show that a large number of indicators have been proposed by different scholars. This observation has a dual interpretation. On the one hand, a clear research trend on the development and/or identification of performance indicators is observed as they can serve as a useful tool for performance measurement. On the other hand, the large number of indicators proposed throughout time and across the world proves that there is no general consensus on a specific set of indicators that could sufficiently measure sustainability performance of construction projects. On top of that, many indicators were found across literature to have similar meaning (e.g. water footprint and water consumption) but are expressed differently. Therefore, grouping such indicators deems appropriate.

As far as the existing frameworks are concerned, the results from the literature review show that a robust, simple and quantified implementation framework with a standardized reporting method within the context of TBL, is missing. This statement comes in line with the research gap mentioned earlier that this thesis attempts to fill. Regarding the assessment procedure provided by private organizations, it is argued that the environmental dimension prevails over the societal and the economic one, and the assessment relies heavily on the experts' judgement.

5. DEVELOPING THE ASSESSMENT METHODOLOGY

After conducting the literature survey which resulted in a sufficient amount of relative information regarding the current state of TBL, key performance indicators and assessment frameworks, the next step refers to the utilization of the collected information for the development of the assessment method. Thus, this section of the report aims to provide answer to the following three issues:

1) Which is the most appropriate set of indicators that will be used for the assessment procedure?
2) What is the relative importance of the selected indicators and how is this importance reflected in the assessment procedure?
3) What is the outcome of the assessment and how is this calculated?

5.1 Filtering process of indicators

A total number of 24, 24 and 23 performance indicators have been identified for the environmental, social and economic dimension respectively. As mentioned in section 3.3.2, the filtering process of indicators is carried out in two stages. In the first stage, indicators with similar content are merged while sector-specific indicators (i.e. applicable only in residential buildings) are removed. In the second stage, the remaining indicators are filtered based on two criteria: variety of sources (triangulations) and frequency of appearance in literature. For the second stage, if in an indicator satisfies at least one of the above criteria, it is included in the final set.

<u>Filtering stage 1</u> (examples)

"Deforestation" appears only once in literature and in the UN indicator framework. This indicator is considered to be covered by the *"Ecosystem/Biodiversity protection"* and, therefore merged.

"Indoor environmental quality" refers only to buildings and therefore excluded from the final set

<u>Filtering stage 2</u> (examples)

"Gender equality" refers to the end of discrimination between men and women and equal pay for work of equal value (Li, Gu, & Liu, 2018). This indicator appear only once in the literature survey and is also included in the UN indicator framework. However, this indicator is not excluded from the final list as it is considered to be covered by the *"Reducing inequalities"* indicator, and, therefore merged.

"CO_2 uptake land" refers to the amount of forestland required to absorb given carbon emissions (Kucukvar & Tatari, 2013) and is appeared only once in a research paper. This indicator is considered as insignificant and excluded from the final list.

"Percentage of community residents who must be relocated due to the project" (Wu et al., 2018) appears only once in literature therefore excluded from the final set.

Table 5.1 Selection process of indicators (Environmental dimension)

	Environmental sustainability indicators	**UN**	**Private institutions**	**Frequency in literature**	**Included in final set**
1	Adaptation and vulnerability to climate change-environment	√	BREEAM	3	√
2	Air quallity around the project	√		3	√
3	Application on energy saving,ecology and intelligent technology	√	BREEAM	2	√
4	CO_2 uptake land			1	X
5	Deforestation	√		1	√ (merged)
6	Disaster risks (quakes/floods)	√	BREEAM	1	√
7	Ecosystem/Biodiversity protection	√	BREEAM/ LEED	9	√
8	Energy performance/Energy consumption	√	BREEAM/ LEED/GPR	9	√
9	Material circularity		BREEAM	2	√
10	Greenhouse gas emissions	√	BREEAM	8	√
11	Indoor environmental quality		BREEAM/ LEED/GPR	3	X
12	Land use			2	X
13	Loss of habitat	√		1	√ (merged)
14	Material resources/ sustainable use of natural resources	√	BREEAM/ GPR	8	√
15	Noise level/reduction		BREEAM/ LEED/GPR	5	√
16	Pollution	√	LEED	2	√ (merged)
17	Protection of water resources	√		2	√ (merged)
18	Recycling of materials and water	√	BREEAM	4	√ (merged)
19	Renewable energy	√	LEED	7	√
20	Site selection			1	X
21	Use of green products			2	X
22	Waste management	√	BREEAM/ LEED	6	√
23	Water and waste water efficiency strategies	√	BREEAM/ LEED	3	√
24	Water footprint		LEED	5	√ (merged)

Table 5.2 Selection process of indicators (Social dimension)

	Social sustainability indicators	UN	Private institutions	Frequency in literature	Included in final set
1	Aesthetics/visual impact		BREEAM/ LEED	2	√
2	Culture and heritage preservation	√		2	√
3	Fair sharing of benefits	√		1	√
4	Gender equality	√		1	√ (merged)
5	Health, comfort and well-being of occupants	√	BREEAM	6	√
6	Wages and benefits	√		3	√
7	Influence on the local economy	√		2	√ (merged)
8	Leisure			1	X
9	Living environment/ Needs assessment of society-people	√		3	√
10	Local participation	√		5	√
11	Local social development	√		1	√
12	Local workforce			2	√ (merged)
13	Market supply and demand			1	X
14	Occupational health and safety	√		6	√
15	Peace and justice	√		2	√ (merged)
16	Percentage of community residents who must be relocated due to the project			1	X
17	Productivity			1	X
18	Reducing inequalities	√		2	√
19	Safety and security	√		2	√
20	Taxes			2	X
21	Transportation infrastructure/accessibility and amenities	√	BREEAM	3	√
22	Use of regional materials	√		2	√
23	User and owner satisfaction		GPR	3	√ (merged)
24	Work created throughout the project cycle	√		3	√

Table 5.3 Selection process of indicators (Economic dimension)

	Economic sustainability indicators	UN	Private institutions	Frequency in literature	Included in final set
1	Innovation management/new product development	√	BREEAM/LEED	7	√
2	Cost management plan			6	√
3	Developing an efficient risk management plan			6	√
4	Financial performance			5	√

5	Effective project control			5	√
6	Efficient allocation of resources			4	√
7	Contribution to GDP	√		3	√
8	Investment amount			3	√
9	Abbility to pay and affordability			3	√
10	Business ethics			3	√
11	Effective change management strategy			3	√
12	Life/endurance of construction and design		BREEAM	2	√
13	Economic and political stability			2	X
14	Design and Construction time			1	X
15	Economic diversity in project affected areas			1	X
16	Flexibility			1	X
17	Gross Operating Surplus			1	X
18	Imports			1	X
19	Integrated management			1	X
20	Percentage of population receiving external benefits in project affected areas			1	X
21	Readjustment for new business environment			1	X
22	Supply chain collaboration			1	X
23	Project output emphasis			1	X

- Note for economic sustainability indicators

The cross-check between literature findings, the UNSDGs and other sources resulted in a very low overlap of indicators for the economic dimension. This is mainly explained by the fact that the UNSDGs are focused in preserving the environment and ensuring social equity while the economic indicators identified during the literature survey were specifically developed for the construction industry. In addition, the studied LEED, BREEAM and GPR frameworks focus merely on the environmental dimension and the economic aspect is neglected. For this reason, the selection of indicators that will form the final set for this dimension is based mainly on the criterion “frequency of appearance in literature”.

5.2 Final sets of indicators

The line of reasoning for the selection of the final sets of indicators has been mentioned earlier in this report. However, this list is not exhaustive. The indicators selected for the assessment procedure are considered to cover sufficiently the main areas of sustainability within the context of a construction project. On the other hand, every construction project is unique and the same applies for the sustainability requirements associated with the project. Thus, it is proposed to add a **project specific** indicator in the list of indicators for every aspect of the TBL. This indicator is optional for the assessment procedure and the content will be defined in mutual consultation with the involved stakeholders.

Since the selection process of indicators has been clarified, the final sets have been determined for the three aspects of sustainability. At this stage, it is more convenient to assign a code on each one of them, for reporting purposes. The short tables with the final sets of indicators with their corresponding codes are presented below while the extended tables with a short description and indicative references, are given in the Appendix D.

Table 5.4 Final set of environmental sustainability indicators

Code	Environmental sustainability indicators
En1	Adaptation and vulnerability to climate change
En2	Air quality around the project
En3	Application on energy saving, ecology and intelligent technology
En4	Disaster risks
En5	Ecosystem/Biodiversity protection
En6	Energy performance
En7	Greenhouse gas emissions
En8	Sustainable use of material resources
En9	Noise level/reduction
En10	Renewable energy
En11	Waste management
En12	Water and waste water efficiency strategies
En13	Material circularity
En14	Project specific (optional)

Table 5.5 Final set of social sustainability indicators

Code	Social sustainability indicators
Soc1	Aesthetics/Visual impact
Soc2	Culture and heritage preservation
Soc3	Fair sharing of benefits
Soc4	Health, comfort and well-being of occupants
Soc5	Wages and benefits
Soc6	Living environment
Soc7	Local participation
Soc8	Local social development
Soc9	Occupational health and safety
Soc10	Reducing inequalities
Soc11	Safety and security
Soc12	Transportation infrastructure/accessibility and amenities
Soc13	Use of regional materials
Soc14	Work created throughout the project cycle/employment
Soc15	Project specific (optional)

Table 5.6 Final set of economy sustainability indicators

Code	Economic sustainability indicators
Eco1	Innovation management
Eco2	Cost management plan
Eco3	Developing an efficient risk management plan
Eco4	Financial performance
Eco5	Effective project control
Eco6	Efficient allocation of resources
Eco7	Contribution to GDP
Eco8	Investment amount
Eco9	Ability to pay and affordability
Eco10	Business ethics
Eco11	Effective change management strategy
Eco12	Lifetime of construction and design
Eco13	Project specific (optional)

5.3 Relative importance of indicators

Every construction project is unique. The same applies also for the sustainability requirements associated with every project. Sustainability is considered as a "cross-cutting issue" with various interpretations among different people (Ametepey, Aigbavboa, & Ansah, 2015). Karji et al. (2019), referring to social sustainability, argue that what might be perceived as sustainable construction practices in one country, might not even satisfy the minimum standards in another country. This is due to the fact that multiple stakeholders have differing interest connected with a project. This section of the report will be devoted to establish the procedure for the allocation of weights for the different indicators that where selected in the previous section. In order to comply with the above statements, the weights will not be predefined. Instead, only the calculation procedure with be provided and the relative importance of indicators will be defined during the assessment procedure according to the assessors' preferences and the project characteristics. The reason behind this choice is that this assessment framework attempts to create a link between the sustainability performance evaluation and the stakeholders' interests.

When a new assessment is carried out for a construction project, the engaging stakeholders are asked to rate the importance of each performance indicator in a 5-point Likert scale. The Likert scale is a psychometric response scale which measures the degree of agreement to a statement in five points (Preedy & Watson, 2010). In our case, the 5-point scale refers to the level of importance of indicators, as they were categorized in the three aspects of TBL. The scale with the corresponding statements is given below:

(1) – Unimportant
(2) – Low importance
(3) – Moderately important
(4) – Very important
(5) – Extremely important

Since various stakeholders are expected to participate in this process, it can be concluded that the indicators will have multiple values. A quite simple and straightforward way to compute weights is by utilizing the measure of Relative Importance Index (RII). The weight (Wx_i) for every indicator (x_i) of the selected set is the corresponding value of the RII, according to equation (1) (Muhwezi, Acai, & Otim, 2014, p. 18):

$$Wx_i = RII = \frac{\sum W}{A * N} \text{ , } (0 \leq RII \leq 1) \quad (1)$$

Where:

W – is the weight given to each indicator by the assessor;

A – is the highest weight (i.e. 5 in this case) and;

N – is the total number of respondents.

5.4 Assessment procedure

The performance assessment procedure is summarized in four sequential steps:

1) Weight definition
2) Scoring system of indicators
3) Weighted Assessment Score calculation
4) Visualization of results in spider diagrams

For every step, an illustration is provided. The values shown in the figures are completely random are used only for demonstration.

<u>Step 1: Weight definition</u>

The first step refers to the determination of the weighting factors for the performance indicators, as described in section 3.2. Almahmoud & Doloi (2015), claim that it is crucial to integrate the differing interests of multiple stakeholders in the assessment procedure in order to bring harmony between the project proposal and sustainability requirements. The creation of a stakeholder map could potentially contribute to the identification of stakeholders, their interests and degree of affecting power regarding the project under assessment. The weight definition can be carried out during the early phases of a construction project, in consultation with the affected stakeholders. In this way, the various stakeholders are engaged in process from the early stages, therefore increasing the chances for a positive outcome, in terms of sustainability. In addition, the requirement of "local participation" in the list of indicators is satisfied.

	Code	Indicator	SH1	SH2	SH3	SH4	N	Σw	RII (weight)
ENVIRONMENT	En1	Adaptation and vulnerability to climate change	5,0	2,0	3,0	3,0	4	13,0	0,650
	En2	Air quality around the project	4,0	3,0	1,0	3,0	4	11,0	0,550
	En3	Application on energy saving, ecology and intelligent technology	2,0	3,0	2,0	4,0	4	11,0	0,550
	En4	Disaster risks	3,0	1,0	1,0	1,0	4	6,0	0,300
	En5	Ecosystem/Biodiversity protection	1,0	5,0	2,5	5,0	4	13,5	0,675
	En6	Energy performance	2,0	3,0	3,0	3,0	4	11,0	0,550
	En7	Greenhouse gas emissions	4,0	3,0	5,0	3,0	4	15,0	0,750
	En8	Sustainable use of material resources	1,0	1,0	3,0	1,0	4	6,0	0,300
	En9	Noise level/reduction	5,0	2,0	2,0	2,0	4	11,0	0,550
	En10	Renewable energy	3,0	3,0	3,0	1,0	4	10,0	0,500
	En11	Waste management	2,0	2,0	2,0	2,0	4	8,0	0,400
	En12	Water and waste water efficiency strategies	4,0	4,0	3,0	3,0	4	14,0	0,700
	En13	Material circularity	1,0	2,0	1,0	4,0	4	8,0	0,400
	En14	Project specific (optional)	2,0	2,0	2,0	2,0	4	8,0	0,400
	Code	Indicator	SH1	SH2	SH3	SH4	N	Σw	RII (weight)
ECONOMY	Eco1	Innovation management	5,0	2,0	3,0	2,0	4	12,0	0,600
	Eco2	Cost management plan	4,0	3,0	1,0	3,0	4	11,0	0,550
	Eco3	Developing an efficient risk management plan	2,0	3,0	2,0	3,0	4	10,0	0,500
	Eco4	Financial performance	3,0	1,0	1,0	1,0	4	6,0	0,300
	Eco5	Effective project control	1,0	5,0	2,0	5,0	4	13,0	0,650
	Eco6	Efficient allocation of resources	2,0	3,0	3,0	3,0	4	11,0	0,550
	Eco7	Contribution to GDP	5,0	2,0	1,0	2,0	4	10,0	0,500
	Eco8	Investment amount	4,0	3,0	5,0	3,0	4	15,0	0,750
	Eco9	Ability to pay and affordability	1,0	1,0	3,0	1,0	4	6,0	0,300
	Eco10	Effective change management strategy	3,0	3,0	3,0	2,0	4	11,0	0,550
	Eco11	Lifetime of construction and design	2,0	2,0	2,0	3,0	4	9,0	0,450
	Eco12	Economic and political stability	4,0	4,0	3,0	2,0	4	13,0	0,650
	Eco13	Project specific (optional)	5,0	2,0	2,0	4,0	4	13,0	0,650
	Code	Indicator	SH1	SH2	SH3	SH4	N	Σw	RII (weight)
SOCIETY	Soc1	Aesthetics/Visual impact	5,0	2,0	3,0	3,0	4	13,0	0,650
	Soc2	Culture and heritage preservation	4,0	3,0	1,0	3,0	4	11,0	0,550
	Soc3	Fair sharing of benefits	2,0	3,0	2,0	4,0	4	11,0	0,550
	Soc4	Health, comfort and well-being of occupants	3,0	1,0	1,0	1,0	4	6,0	0,300
	Soc5	Income	1,0	5,0	2,0	5,0	4	13,0	0,650
	Soc6	Living environment	2,0	3,0	3,0	3,0	4	11,0	0,550
	Soc7	Local participation	5,0	2,0	1,0	2,0	4	10,0	0,500
	Soc8	Local social development	4,0	3,0	5,0	3,0	4	15,0	0,750
	Soc9	Occupational health and safety	1,0	1,0	3,0	1,0	4	6,0	0,300
	Soc10	Reducing inequalities	5,0	2,0	2,0	2,0	4	11,0	0,550
	Soc11	Safety and security	3,0	3,0	3,0	1,0	4	10,0	0,500
	Soc12	Transportation infrastructure/accessibility and amenities	2,0	2,0	2,0	2,0	4	8,0	0,400
	Soc13	Use of regional materials	4,0	4,0	3,0	3,0	4	14,0	0,700
	Soc14	Work created throughout the project cycle/employment	1,0	2,0	1,0	4,0	4	8,0	0,400
	Soc15	Project specific (optional)	5,0	2,0	2,0	2,0	4	11,0	0,550

Figure 5.1 Illustration of the weight calculation (own illustration)

Step 2: Scoring system of indicators

The project under consideration is assessed with the help of the selected indicators, in the three pillars of sustainability. In order comply with ISO 14040 and ISO 14044 standards for life-cycle assessment, as described by UNEP/SETAC (2011), a panel of (at least) three independent consultants should be appointed to carry out separate assessments individually. The reason behind the indication for independent consultants is to exclude bias from the assessment as the people already involved in the project have their own, differing interests.

The assessment score (ASx_i) is carried out on a 5-point Likert scale for every indicator of the three dimensions separately, where the rating refers to:

(1) – Extremely bad performance
(2) – Moderately bad performance
(3) – Sufficient performance
(4) – Moderately good performance
(5) – Exceptional performance

Environment	
Code	AS(xi)
En1	5,0
En2	4,0
En3	1,0
En4	2,0
En5	5,0
En6	2,0
En7	4,0
En8	2,0
En9	3,0
En10	3,0
En11	2,0
En12	3,0
En13	3,0
En14	4,0

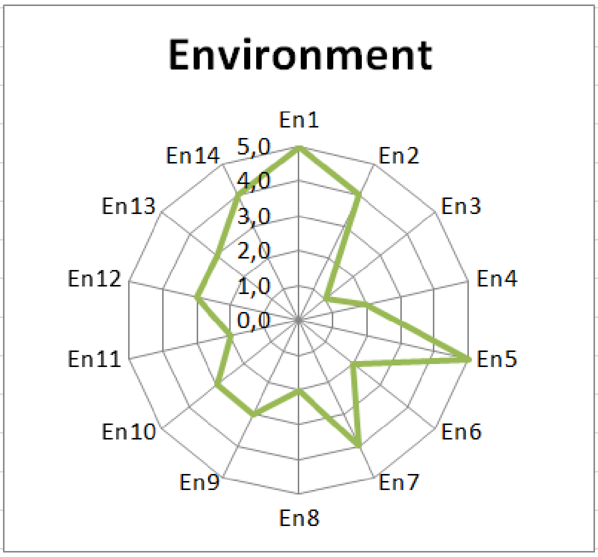

Figure 5.2 Illustration of the scoring system-Environment (own illustration)

Society	
Code	**AS(xi)**
Soc1	3,0
Soc2	4,0
Soc3	2,0
Soc4	5,0
Soc5	3,0
Soc6	2,0
Soc7	4,0
Soc8	2,0
Soc9	3,0
Soc10	5,0
Soc11	2,0
Soc12	4,0
Soc13	5,0
Soc14	2,0
Soc15	4,0

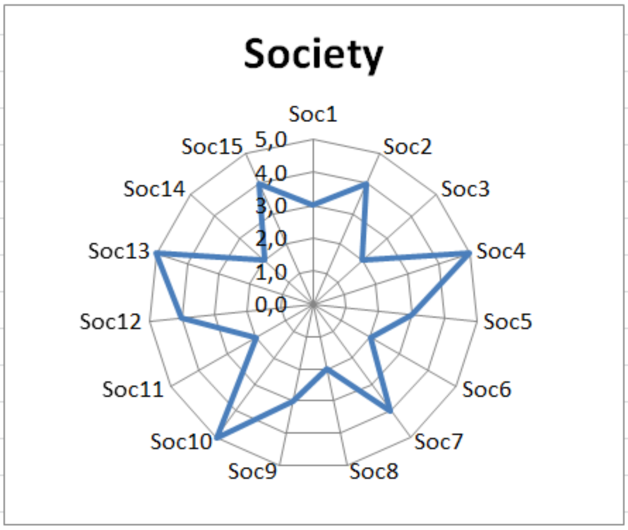

Figure 5.3 Illustration of the scoring system: Society (own illustration)

Economy	
Code	**AS(xi)**
Eco1	4,0
Eco2	2,0
Eco3	5,0
Eco4	4,0
Eco5	4,0
Eco6	4,0
Eco7	4,0
Eco8	4,0
Eco9	4,0
Eco10	2,0
Eco11	3,0
Eco12	2,0
Eco13	4,0

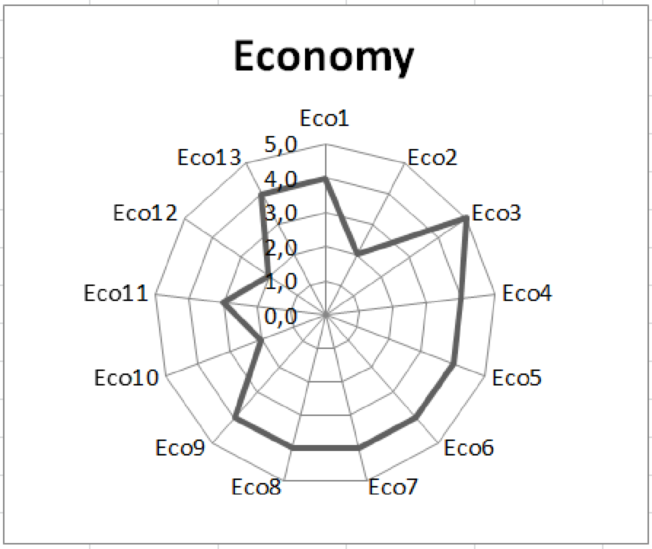

Figure 5.4 Illustration of the scoring system: Economy (own illustration)

<u>Step 3: Weighted Assessment Score calculation</u>

With the help of a spreadsheet, the Weighted Assessment Score ($WASx_i$) for each indicator is calculated according to equation (2):

$$WASx_i = ASx_i * Wx_i \quad (2)$$

and the Total Weighted Assessment Score (TWAS) for every dimension is calculated as a weighted sum, according to equation (3):

$$TWAS = \sum_{i=1}^{n} WASx_i * Wx_i \quad (3),$$

Where:

n= the total number of indicators in this dimension

In this step, it is also important to calculate the minimum, maximum and acceptable weighted assessment scores, for benchmarking purposes.

The minimum score for each dimension would occur if all indicators were evaluated as "(1) - extremely bad performance":

$$minTWAS = \sum_{i=1}^{n} 1 * Wx_i \quad (4)$$

Correspondingly, the maximum score is calculated for every indicator evaluated as "(5) - exceptional performance ":

$$maxTWAS = \sum_{i=1}^{n} 5 * Wx_i \quad (5)$$

Since the assessment is carried out on a 5-point Likert scale, it makes sense that the threshold would be defined as if every indicator was assessed as "(3) – sufficient performance"

$$suffTWAS = \sum_{i=1}^{n} 3 * Wx_i \quad (6)$$

Step 4: Visualization of results in spider diagrams and bar charts

Once the final values have been computed, the results will be plotted in spider diagrams and bar charts to facilitate easy communication between the relevant parties and allow the decision makers to focus on specific indicators to improve the overall performance.

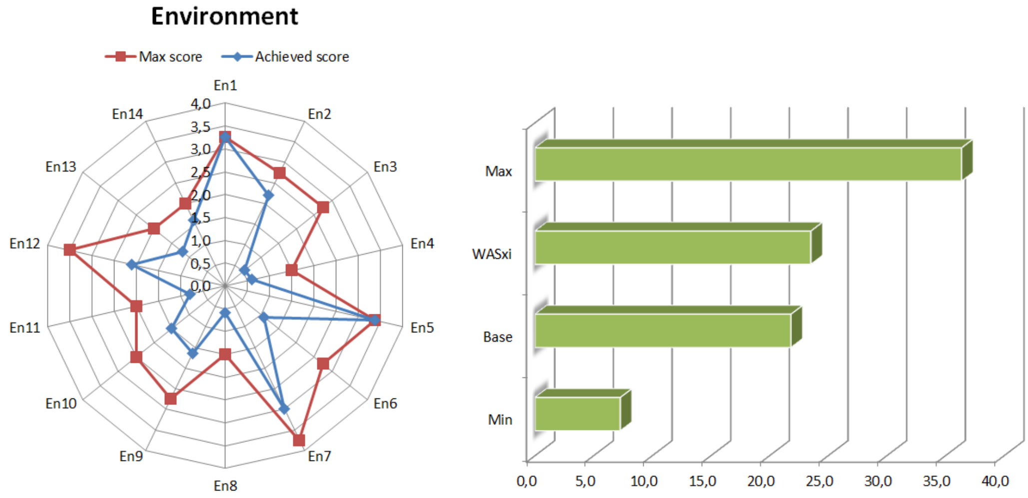

Figure 5.5 Spider diagram and bar chart: Environment (own illustration)

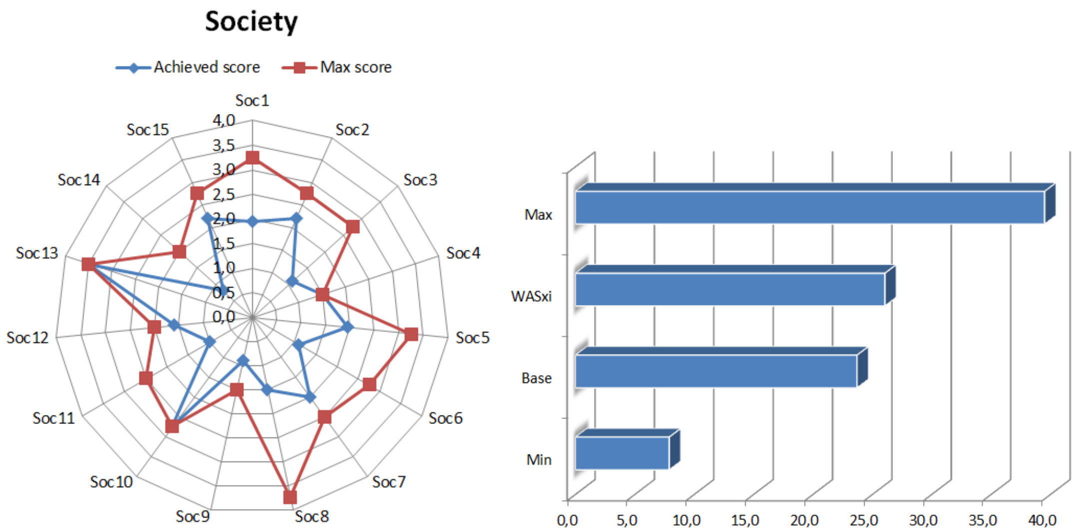

Figure 5.6 Spider diagram and bar chart: Society (own illustration)

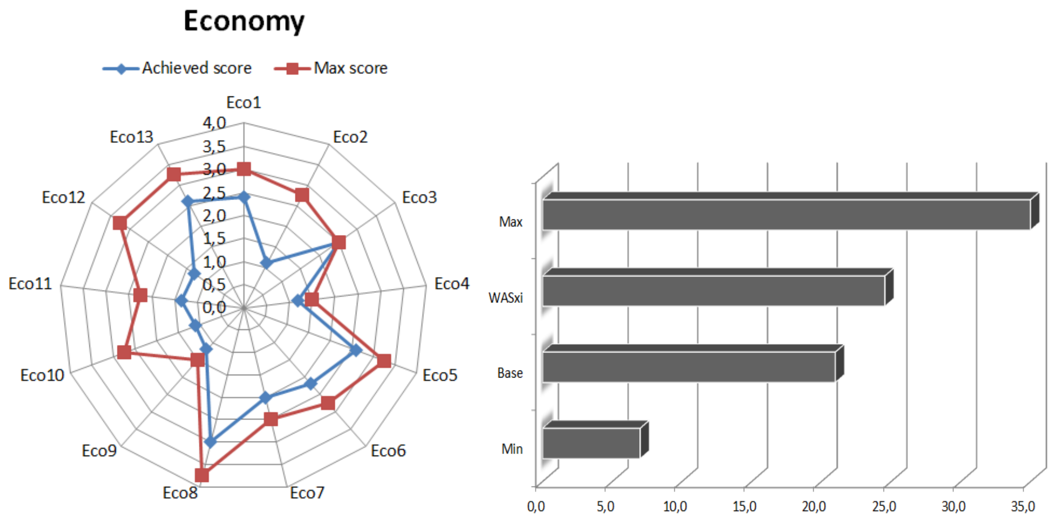

Figure 5.7 Spider diagram and bar chart: Economy (own illustration)

6. CASE STUDY

6.1 Introduction

The case study method is utilized in order to examine the feasibility of the proposed assessment methodology and compare it with the current practices. A sustainability expert from the selected project was approached to participate in the process and provide an insight in the current practices as well as a critical review on the proposed assessment tool. The information provided by the expert is considered to be representative for the complete team involved in the project as it refers to the same project goals, for the same client .The case study application is carried out in three sequential steps:

1. Information exchange: Relevant information regarding sustainability performance was communicated through e-mail in order to gain an insight on how sustainability issues are addressed in the studied project. Moreover, publicly available information for the project was shared. These were further discussed in an online interview.
2. Weight definition: The full list with the selected indicators was distributed to the participant, in the form of a questionnaire, prior to the online interview, asking her to rate each indicator on a scale from 1 to 5, according to the degree of importance with regards to the studied project. The reasoning for the rating was also provided by the expert.
3. Online interview: Once the importance of the given indicators has been defined, the indicators with the highest importance are selected for further assessment. The main reasons behind this choice are the limited availability of participant and the restricted timeframe in which this thesis is carried out. During the interview, the proposed assessment method was presented and explained to the sustainability expert and the possibility of incorporating it in the company, was explored. In addition, the assessment tool was evaluated in terms of workability and appropriateness.

6.2 Description of interview questions

A description of the interview questions is given below. However, during the interview the discussion was not restricted only to these questions and the interviewee was probed with follow-up questions and was encouraged to share more information that would help gain a better overview of how construction sustainability is applied in practice.

1. How do you measure sustainability performance for the given project and what are the results?

2. How are the aspects of social and economic sustainability addressed in the ViA15 project? Again, how do you measure the project performance in these aspects and what are the results?
3. You were provided with a list of indicators for the three dimensions of the TBL. Which ones do you find the most important for the Via15 project?
4. What would be the assessment score on a scale from 1 to 5, for the most important indicators and based on what criteria?
5. Given the different nature of various indicators (some are quantifiable while others are more descriptive), what criteria would you use to evaluate the performance of the project?

At this point of the interview, the proposed assessment methodology was presented and explained to the expert.

6. Do you believe that the provided set of indicators cover sufficiently the three dimensions of the TBL?
7. How would you judge the workability of the assessment procedure?
8. How would you judge the way the results are presented?
9. What are the limitations of the proposed method?
10. Would you incorporate this tool in your company?
11. Is the tool applicable in different kinds of projects?

6.3 Studied project

6.3.1 Project information

The selection of the case study was made upon two main criteria: Firstly, the project should be in its early construction phase. This would mean that the project is being constructed with the latest available sustainability standards. Secondly, the project should have relatively complex sustainability requirements in terms of environmental protection, social justice and economic prosperity.

The project selected as a case study is named ViA15, a large infrastructure project in the Netherlands, currently in its early construction phase and is expected to start operating in phases between 2022-2024. The project is awarded to the GelreGroen (Dura Vermeer, Besix, Hochtief and John Laing) consortium as a large Design, Build, Finance and Maintain (DBFM) contract. The contract amount is specified at approximately 570 million Euros. Rijkswaterstaat, as the client of the project, made the selection based on both price and quality, also known as Economically Most Advantageous Tender (EMAT) criteria. Sustainability along with risk management and traffic hindrance were the most important criteria for the selection process. The goal of the project is to improve traffic flow in the A15 and A12 motorways as well as the traffic flow in the regional road network of the Gelderland province. The project consists of three parts: (1) extending Motorway A15 with 2x2 lanes and connect it with Motorway A12 (2) widen Motorway A15 by adding extra lanes in specific parts to improve traffic flow and (3) widen Motorway A12 by adding extra lanes in specific parts to accommodate the increased traffic flow. Some parts of the road require the construction of bridges while other parts will be sunk into the ground in the form of a tunnel. The future benefits of the project are summarized by the client as (Rijkswaterstaat, n.d.):

-Improved accessibility of the region;

-The Netherlands will create another route connecting the port of Rotterdam and main cities with the European hinterland;

-Traffic flow is improved by constructing a reliable and safe motorway network;

-Both the central government and the region around the motorways will benefit economically;

-The project will lead to increased quality of life and flood safety in the area.

This specific project was considered as a suitable case study since it crosses areas of protected nature as well as inhabited regions, therefore creating nuisance to the environment and affecting nearby residents. Moreover, the contract value (570 m.Eur) indicates that the economic aspect of the project is highly important. The complexity of project, with regards to sustainability issues, is also reflected in the list of requirements set by the client, as it was confirmed by the sustainability consultant working in the project. The client of the project states that measures have been taken to limit the nuisance created by the construction activities and the contractor has adopted extra measures (beyond minimum requirements) with regards to nuisance and environmental protection (Rijkswaterstaat, n.d.). Some examples of the adopted measures are presented below:

-Noise reduction: Noise barriers are placed in sections where the distance between the motorways and houses is less than 40 meters.

-Sound and vibration: The design has been optimized to require less foundation piles which means less vibrations due to drilling and driving piles into the ground.

-Groundwater: In locations where the road has to be sunk, the influence on the groundwater flow is minimized by optimizing the bottom height of the section.

-Attention to nature: In order to mitigate the impact on the affected ecosystems, various measures have been adopted such as nesting boxes for owls, sparrows and other birds and underpasses for amphibians and other animals.

At this point, it is important to note that during the interview, the interviewee stated that construction works are currently on hold due to opposition from environmental groups.

6.3.2 Current practice applied to the project

During the interview and in previous communication through email, the interviewee was asked to provide information on sustainability practices applied to the ViA15 project. The information shared gives an insight on how the notion of sustainability is addressed in a large infrastructure project in the Netherlands as well as if the approach followed adheres to the TBL principles.

From the project's perspective, only the environmental dimension of the TBL was addressed directly and the organization was obliged by the client to report results on various environmental sustainability aspects. In case the minimum requirements for environmental sustainability were not met, the client would impose fines to the contractor. On the other hand, the remaining two aspects of sustainability were not completely neglected by the contractor. For instance, referring to the indicator "wages and benefits" from the social aspect, the company claims that it provides competitive salaries and other benefits to its employees in order to maintain a specialized workforce. Similarly, for the economic pillar, the company develops effective cost and risk management plans in order to execute its projects on time, within budget and with the required quality. However, these items are not regarded as sustainability issues but are reflected in the company's corporate responsibility and management philosophy.

Based on the aforementioned, the notion of sustainability is addressed based on two assessment systems. These are the CO_2 Performance Ladder and the Environmental Cost Indicator (ECI).

The CO_2 PERFORMANCE LADDER (Foundation for Climate Friendly Procurement and Business, n.d)

This tool has been initially created by the Dutch railway infrastructure provider and is now owned by the Foundation for Climate Friendly Procurement and Business (SKAO). The instrument can be used by organizations as a CO_2 management system but also as a procurement tool as well. This is a commercial product which means that organizations have to invest a certain amount of money to acquire one of the certificates on the Ladder and in return, they will achieve lower energy costs, less material usage and innovations. The Ladder certificates are issued in five levels. A certificate up and until level 3 means that an organization reduces its own carbon emissions across its projects. Level 4 and 5 mean that the organization is also committed to reduce CO_2 emissions across its supply chain and sector.

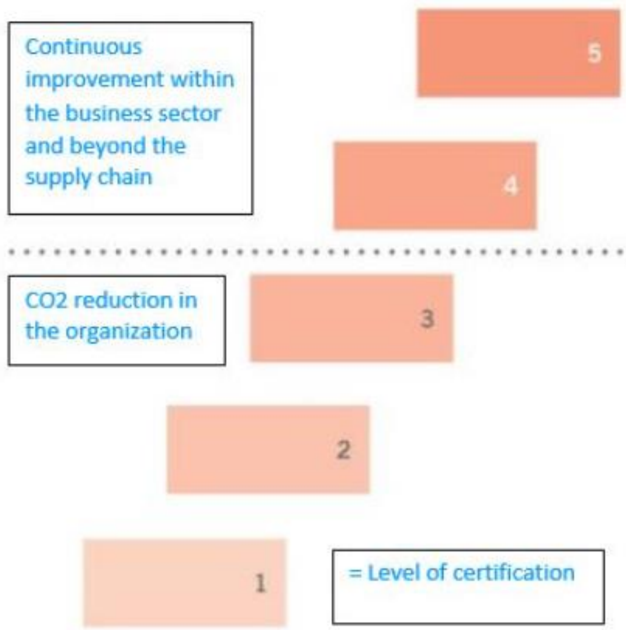

Figure 6.1 The five levels of certification in the CO_2 Performance Ladder (Foundation for Climate Friendly Procurement and Business, n.d)

The requirements based on which the certificates are issued are based on four perspectives, namely:

1) Insight: To determine different streams of energy and carbon footprint of the organization.
2) Reduction: The development of ambitious goals and targets for the reduction of carbon emissions.
3) Transparency: Information sharing regarding the organization's policies of CO_2 reduction.
4) Participation: To be involved in business sector initiatives regarding the reduction of carbon emissions.

The certifications are reviewed annually to ensure continuous improvement and commitment towards CO_2 reduction.

The organization that is part of the consortium realizing the project has been awarded with a Level 5 certificate which means that besides reducing its own carbon emissions, it is also undertaking initiatives to reduce carbon emissions in the overall construction sector and the supply chain. At this point it is important to note that, according to the interviewee, every large contractor in the Netherlands is certified with a Level 5 in the CO_2 Performance Ladder. A certificate in a lower scale would have consequences in the ability of the contractor to win tenders.

<u>The Environmental Cost Indicator (ECI)</u> (Ecochain, n.d.)

The ECI is a metric that reflects all the relevant environmental impact presented as the "shadow price" of a product or project. The ECI is calculated by conducting life cycle assessment for the emissions produced of a product. The results from life cycle assessments have been recently used in public procurement tenders in the Netherlands and can potentially determine the winning bid. The ECI is embodied in procurement tenders by providing a fictional discount on the final offer and the amount of the discount is determined based on the environmental costs. The lowest environmental costs receive the highest discount and vice versa which in turn means that environmental performance could play a significant role in winning tenders, even if the actual price is higher.

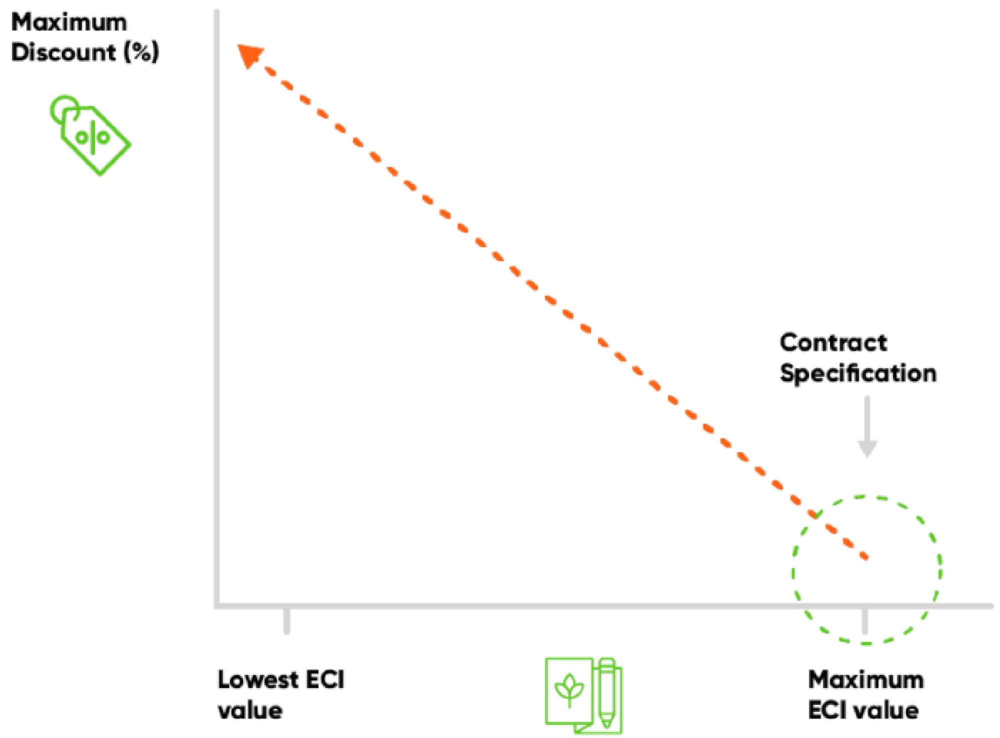

Figure 6.2 ECI discount in tenders (Ecochain, n.d.)

The ECI is calculated by following the steps for a life cycle assessment. This procedure consists of (Ecochain, n.d.):

1) Collect input data on material resources, energy requirements and processes used in the product under examination.
2) Calculation of emissions that these inputs produce, for example in terms of CO_2, PO_4, NOx or other pollutants.
3) Translation of emission data into impact categories, such as climate change or eutrophication according to complex scientific models on the basis of emissions to air, water and soil, and substance properties such as biodegradability, toxicity, etc.
4) Weighting of impact categories on the basis of the shadow price method. The shadow price is the highest cost level acceptable for governments per unit of emission control.

In order to end up with a single and comparable metric, the ECI scores are weighted and merged into one final, monetary value. An illustrative example of the impact categories and the weighting factors is given in figure 4.4.

The ECI for the studied project was considered as confidential information and could not be shared with the author.

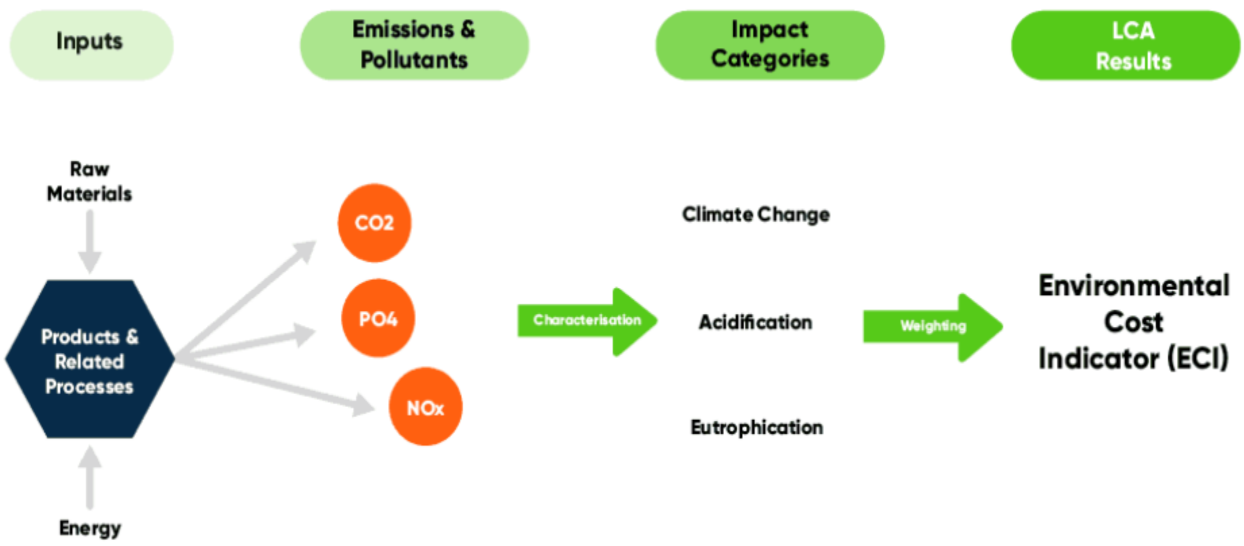

Figure 6.3 ECI calculation (Ecochain, n.d.)

Impact category	Unit	Weighting Factor (€/ unit)
Global warming	kg CO2-eq	0,05 €
Ozone depletion	kg CFC-11-eq	30,00 €
Acidification of soil and water	kg SO2-eq	4,00 €
Eutrophication	kg PO4 3--eq	9,00 €
Depletion of abiotic resources – elements	kg Sb-eq	0,16 €
Depletion of abiotic resources – fossil fuels	kg Sb-eq	0,16 €
Human toxicity	kg 1,4 DB-eq	0,09 €
Freshwater ecotoxicity	kg 1,4 DB-eq	0,03 €
Marine water ecotoxicity	kg 1,4 DB-eq	0,0001 €
Terrestrial ecotoxicity	1,4 DB- eq	0,06 €
Photochemical oxidant creation (Smog)	kg C2H4	2,00 €

Figure 6.4 Impact categories and weighting factors example (Ecochain, n.d.)

6.4 Critical review of the proposed tool

After gaining an insight on how sustainability issues are being treated in practice, the proposed assessment method was presented to and discussed with the expert.

The list of indicators was communicated with the sustainability expert prior to the online interview and she was asked to rate the importance of each indicator on a scale from 1 to 5, with regards to the Via15 project. The file can be found in Appendix E. According to the interviewee, the most influential indicators for the project again belonged to the environmental aspect while several indicators from the social aspect were considered important but with a lower rating. The importance assessment of the indicators was made by the interviewee on the basis of client requirements. Those indicators which are connected directly with client requirements are rated with 5 (Extremely important). Indicators that are not enlisted in the client's requirements but have an indirect effect are rated with 3 (Moderately important). Lastly, indicators rated as low importance (scale 2) refer to general project requirements but they are not listed as sustainability requirements.

Based on the interviewee's answers, the most important indicators were:

-Ecosystem/Biodiversity protection

-Energy performance

-Greenhouse gas emissions

The indicators that affect indirectly the project performance on the ECI were:

-Sustainable use of material resources

-Material circularity

-Use of regional materials

Some examples of other indicators that were included in the list of client's requirements but were not mentioned as sustainability requirements were:

-Air quality around the project (Environment)

- Noise level/reduction (Environment)

-Renewable energy (Environment)

-Local participation (Society)

-Occupational health and safety (Society)

-Work created throughout the project lifecycle/Employment (Society)

The complete list of indicators including the expert's opinion concerning their importance can be found in the Appendix D. As it is clearly visible, a significant amount of indicators were left unrated. During the interview, the participant was asked to explain why that many indicators did not receive a score. The answer provided was that, according to her personal opinion, all these indicators were referring to important aspects of the projects. However, since they were not included in the client's list of requirements, all of them would receive the lowest rating from the given scale (1 out of 5) or even zero if it was possible. The explanation for this choice was that the team involved in the project was focused exclusively on trying to meet the client's requirements and had neither the time nor the resources to deal with additional indicators.

Another observation was that none of the indicators from the economic dimension received a rating. The expert was asked if she considered them as completely insignificant. The response given was that, again, these indicators are of significant importance to the project, however, they refer to the overall management system of the company and they were not treated as sustainability issues. A characteristic example was the indicator “cost management plan” where the expert claimed that the company allocates a great amount of time and resources to develop accurate and efficient cost management plans because otherwise, its own viability would be at risk. However, it was not treated as a sustainability issue.

The general observation was that the team of sustainability experts perceived the notion of sustainability as environmental protection and restoration while the other two dimensions were not perceived as aspects of sustainability.

Performance assessment

The next step after defining the most important indicators for the ViA15 project was to examine the feasibility of measuring the project’s performance on these indicators. The calculation procedure as explained in chapter 3 was presented and the interviewee was requested to provide an assessment score that reflects the project’s performance. The reply was that the indicators from the environmental dimension which received an importance rating of 3 or 5 are sufficiently covered by the ECI. Although the exact value of the ECI could not be disclosed with the author, it was stated that the final value was significantly better than the minimum requirement set by the client. This was also reflected in the fictional discount that the consortium received during the tendering stage. As a result, the score achieved would be a 4 or 5 but the exact number could not be defined as the respondent would first need to be provided with a clear explanation on the difference between the scales. In other words, the response was that they know that they are performing better, but they were not able to say if their performance is slightly better or extremely good.

Regarding the indicator “Noise level/reduction” which is considered as an important issue on the project according to the client, the contractors will use a new type of asphalt concrete to reduce the noise level caused by vehicles that will use the road. Additionally, sound barriers will be placed in specific positions where the motorway is close to residential areas to reduce the nuisance to the nearby houses caused by traffic. These measures contribute towards meeting the client’s requirement on noise level, therefore the achieved score would correspond to a 3 of the given scale.

As far as the societal indicators are concerned, the respondent was not able to provide a justified performance score due to the descriptive nature of the indicators besides that most of them were considered as important or even required by the client. With regards to the "wages and benefits" indicator, the interviewee claimed that the company provides competitive salaries to maintain specialized and experienced employees in its workforce, however, assigning a number from 1 to 5 would be highly subjective and could only be done if a specific scale with amounts was given. The same applies for other indicators, such as the "local participation". The client together with the contractor organized regular meetings with surrounding stakeholders (in Dutch called "keukentafelgesprekken" or "kitchen table discussions" as the English translation is) where they participated in the process by being informed on the project developments and raising their concerns regarding various aspects. Again, the respondent claimed good performance on these indicators but assigning a specific score with a sufficient explanation was not made possible.

Regarding the economic dimension, the sustainability expert did not provide an evaluation at all since she claimed that it did not fall under her area of expertise. This fact however does not mean that the indicators included in the economic pillar of sustainability are not considered as vital for the project and the company itself. On the contrary, the company allocates vast amounts of time and resources to develop cost management plans, risk management plans, innovative solutions and so on. From the interviewee's perspective, these issues refer to the company's management philosophy and are not considered as sustainability aspects. One step further, performance evaluation on these aspects would not be disclosed as sustainability results.

When the interviewee was asked to share her opinion on which criteria could be used to evaluate the project performance against certain indicators (considering the quantitative and qualitative nature of indicators), the response taken was that the comparison with other projects of the company could be an option. However, this would require well organized and accessible databases.

<u>Validation of methodology</u>

The following questions were asked to the sustainability expert with a dual purpose: Firstly to validate the proposed assessment method and secondly, to receive valuable feedback based on which further adaptations to the method would be proposed. Below, a short description of questions and answers is provided:

-Question: *"Do you believe that the provided set of indicators cover sufficiently the three dimensions of the TBL?"*

The answer provided was that indeed the provided set of indicators is representative of the three aspects of sustainability, however there is a confusion on certain indicators from the social and economic dimension. It is not very clear whether they provide assessment on a project level or at a company level

-Question: *"How would you judge the workability of the assessment procedure"?*

According to the interviewee, the presented assessment method is very clearly structured and the calculation procedure is quite straightforward. The computation of the final values is easy to understand. The problem exists on providing a solid explanation on the scores achieved which is a highly subjective matter. The various parties involved in the project have differing opinions on the performance achieved, especially when they do not have full access to the project information. For example, the project may operate 100% from renewable energy but if this information is not communicated properly, people would still claim that the project performs poorly in this indicator.

Question: *"How would you judge the way the results are presented?"*

The response taken was that it is very clear that the intention is to minimize the gap between achieved and maximum performance. It is also easy to identify the indicators with poor performance that have a significant impact on the project. The respondent suggested to couple indicators with activities to improve performance. For instance, local participation could be enhanced by publishing project information on the news and holding stakeholders meeting on a regular basis. The presentation of results in charts also facilitates easy communication with the interested parties.

Question: "What are the limitations of the proposed model?"

At first, the respondent found it extremely difficult to evaluate certain indicators on a scale from 1-5. If there are specific client requirements then the assessment can be made on the basis of meeting the client's requirements. For the rest, comparison with similar projects of the company would be an option but again, this would be highly subjective and it would require databases. There are also time and cost limitations to apply such a model. If this is not a required by the client then it would be really hard to convince the management team to spend time on it.

Question: *"Would you apply this tool in your company?"*

The interviewee stated that, on the one hand, people would not very easily agree to do extra work without seeing a direct benefit. Although the indicators provided in the model refer to important aspects of the projects, the client is the one who pays and sets the requirements. On the other hand, the company claims to be truly committed to sustainability and has adopted four UN goals on sustainable development. They use their own KPIs to measure performance and contribution towards these goals. Taking the "extra mile" could give the company a strategic advantage in the future as these sustainability issues can be translated into client requirements and they will be ready for it. At this point however, it was not considered feasible to use such a tool, unless it was asked by the client.

Question: *“Is the tool applicable in different kinds of projects?”*

From the interviewee’s perspective, every project is unique which means that maybe some indicators will be more important than others. The model could be applied in other kinds of projects however the weights would be different and maybe additional indicators have to be added, in line with client and project requirements.

6.5 Key takeaways from the case study

It can be concluded that, for the studied project, the environmental dimension prevails over the societal and economic aspects of the TBL. Besides the fact that both the client and the contractor consider themselves as truly committed on providing sustainable projects, results are reported only in terms of CO_2 emissions. The social and economic dimensions are not neglected on the project level. Some societal issues such as local participation and the well-being of users are addressed through client requirements while others such as income and employment are reflected in the company’s vision on corporate responsibility. With regards to the economic dimension, the majority of indicators pertain to the company’s management system. The main observation was that sustainability is perceived as environmental protection and preservation while the other pillars are not treated as sustainability aspects.

The critical review of the proposed model confirmed that the proposed set of indicators covers adequately important aspects of project within the context of TBL, however, quantitative reporting on certain indicators was found impractical and highly subjective. The straightforward calculation procedure and the clear structure of the model would facilitate easy communication with the relevant parties and motivate decision makers to improve poor performance. The main driver for the company’s effort to report sustainability results are the client’s requirements. The construction sector is a highly competitive market and the company would employ such an assessment tool only if it foresees tangible financial benefits.

7. REVISED ASSESSMENT METHOD AND PROPOSAL OF A CONCEPTUAL FRAMEWORK

The case study revealed some weaknesses of the proposed method and this part of the report aims to improve these weaknesses through adaptations to the assessment tool and by proposing a conceptual framework for implementation where roles and procedures will be clarified. The case study confirmed the literature findings which indicated that the implementation of the TBL framework in the construction industry is rather vague and insufficient (World Economic Forum, 2016). The main intention is to make the model more attractive for contractors to integrate it in their management philosophy by taking into consideration the observations from the case study and the suggestions from Taylor and Fletcher (2006) for practicality, flexibility and resource requirements.

7.1 Adaptations to the assessment method

During the interview with the sustainability expert, the confusion between indicators was stressed. The indicator “Eco10 – Business Ethics” is considered to be closely connected with the overall management philosophy of the company and cannot be examined from the project perspective. For that reason, this indicator is excluded from the final set. It is considered that the rest of the indicators can sufficiently describe a project’s performance on sustainability and no further additions or removals are needed. However, it has to be clear to the potential users of the methodology that it refers to sustainability performance of projects, not companies.

The limited availability of time and resources for those managing the sustainability aspect of projects was stressed during the case study. The proposed method needs to be more flexible with the requirement for three external consultants to perform the assessment. Thus, the suggestion from ISO 14040 and 14044 will be used only as an indication and the actual number of consultants can be tailored according to the project’s goal, scope and available budget. The requirement for external validity however, remains in place since it will help to reduce bias in the assessment process.

Another adjustment that would add value to the process of evaluating a project’s sustainability performance is the creation of a list with criteria to justify the scoring of each indicator. The matter of subjectivity in the assessments is highlighted in the literature as well as in the case study. In order to reduce subjectivity in the assessment procedure, a column will be added next to the performance score of indicators where the criteria used to justify the score of each indicator will be presented.

A hybrid approach is suggested in terms of assessment criteria where evaluation can be carried out in two ways: Evidence-based and Non-evidence based. The first option presupposes the availability of data to justify the evaluation outcome. Naturally, evidence-based assessment is preferred as it leaves no room for doubt over the assessment. In case of absence of reliable data to justify the performance assessment, the second option comes into power where more subjective judgements are introduced but it is considered to be a fair trade-off, as in this way, important aspects of the project are included in the assessment.

The criteria suggested below were discussed during the case study and derive from the literature studied. The suggested criteria together with an illustrative example are given below:

Evidence-based of primary criteria (preferred, if applicable)

- Standards and minimum requirements: If there is a predefined standard or client requirement that sets the minimum acceptable level of a certain indicator, then this would correspond to the scale 3 (Sufficient performance) of the Likert scale and any score lower than that could not be accepted. Slightly better or far better performance would correspond to scale 4 or 5 respectively. Again, there is a certain degree of subjectivity when scoring 4 or 5 but substantially reduced.
- Comparison with similar projects: Project performance on certain indicators could be compared with (past) similar projects in order to provide a score. In that case, the point of reference would be the performance achieved in the (past) similar project and it would correspond on score 3 in the Likert scale. Worse or better performance of the project under consideration would correspond to scores 1 and 2 or 4 and 5 respectively.

Example:

The creation of an evaluation rubric would help the practitioners carry out the assessment. Suppose that the indicator “Renewable energy” is examined and there is a minimum requirement set by the client to use at least 50% energy from renewable sources to operate the project. Alternatively, if there was not a predefined standard or minimum requirement, suppose that there is a past project with similar characteristics where the achieved percentage of renewable energy in the final energy mixture was 50%. The scoring system would look like:

Indicator: *En10-Renewable energy*	
Assessment scale	**Assessment criteria**
5- Exceptional performance	≥75% of energy coming from renewable sources
4- Moderately good performance	55%-75% of energy coming from renewable sources
3- Sufficient performance	50% (±5%) (min. requirement or achieved performance in past, similar projects)
2- Moderately bad performance	25%-45% of energy coming from renewable sources
1- Extremely bad performance	≤25% of energy coming from renewable sources

Non-evidence based or secondary criteria (if evidence-based assessment is not possible)

Use of questionnaire survey: Questionnaire surveys can be conducted targeting stakeholders affected by the project and asking them to state their degree of satisfaction with the project performance on certain aspects. The answers can be requested on the 5-point Likert scale and the assessment score would be represented by the average value observed in the answers provided.

Example:

Suppose that the indicator "Aesthetics/Visual impact" is examined. This constitutes a qualitative indicator which is extremely difficult to measure. Assessment can be performed with the use of a questionnaire survey, targeting the nearby residents affected by a new construction project. In that case, the question would be: "On a scale from 1 (extremely disappointed) to 5 (very satisfied), how satisfied are you with the aesthetic outcome?"

Indicator: *Soc1- Aesthetics/Visual impact*	
Assessment scale	**Assessment criteria**
5- Exceptional performance	5 – Very satisfied
4- Moderately good performance	4 - Satisfied
3- Sufficient performance	3 – Neutral/Acceptable
2- Moderately bad performance	2 - Disappointed
2- Extremely bad performance	1 – Extremely disappointed

Expert's judgement: Assessment can be carried out based on the opinion of experts in the field of sustainability. This criterion entails a high degree of subjectivity, however professionals with a proven experience and education in the field of sustainability could provide a justified assessment, especially if they act as external consultants.

Example:

Suppose that the indicator “Health comfort and well-being of occupants” is examined for an new motorway project. A highway expert could examine various aspects such as road safety, travel time and connectivity with other infrastructures (ports, airports, etc.) and provide an assessment based on the findings

Indicator: *Soc4-Health, comfort and well-being of occupants*	
Assessment scale	**Assessment criteria**
5- Exceptional performance	Great improvement in road safety, substantial reduction in travel time and excellent accessibility to other amenities
4- Moderately good performance	Increased road safety and reduced travel time
3- Sufficient performance	Standard road safety and no significant difference in travel time
2- Moderately bad performance	Standard road safety but increased travel time due to possible traffic jams
3- Extremely bad performance	Deteriorating accessibility to amenities by cutting of secondary access roads

7.2 A conceptual framework for the integration of sustainability assessment throughout the entire project life cycle

In order to make sound choices on construction products, it is important to consider the complete life cycle of a project. A holistic evaluation of total impacts from “cradle to grave” of a construction project is necessary for the relevant parties to make informed decisions (Life Cycle Initiative, n.d.). According to the ISO standard for Buildings and constructed assets (International Organization for Standardization , 2017), the life cycle of a construction asset can be divided in four distinct phases: Planning, Construction, Operation and End of life. Azapagic (2004) supports that systems thinking could help achieve sustainability goals and targets by adhering to the following steps:

- Identify stakeholders and their sustainability interests
- Develop a sustainability strategy to confront sustainability issues
- Measure and monitor performance with the help of appropriate indicators
- Evaluate progress and commit to continuous improvement
- Ensure interraction with stakeholders

The proposed framework relies on the findings from the literature study and is developed taking into condideration the observations from the case study. It integrates the indicator-based assessment methodology and the principles mentioned by Azapagic under the life cycle perspective.

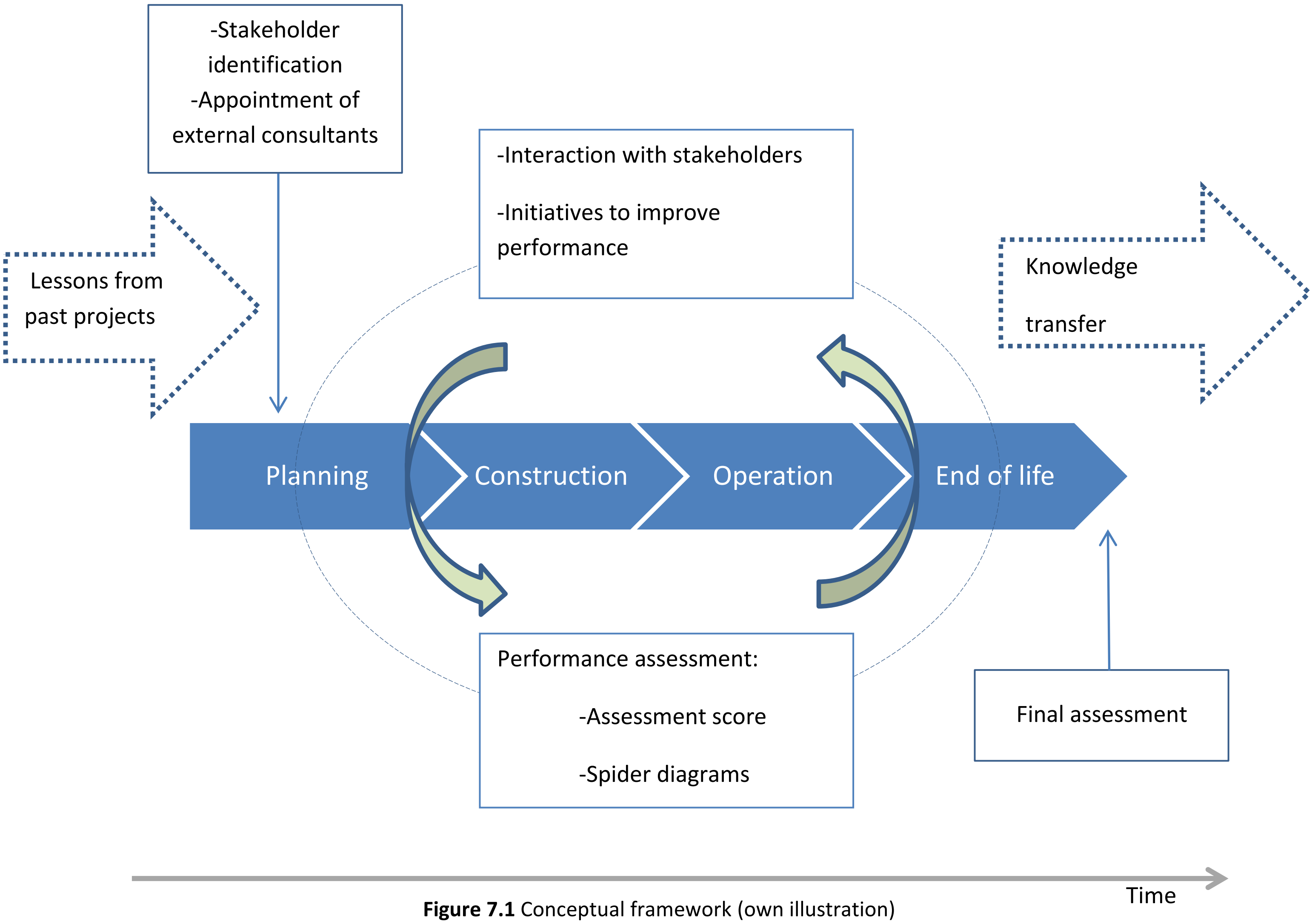

Figure 7.1 Conceptual framework (own illustration)

Key takeaway lessons from past projects are used as input to the new project in order to form a sustainability strategy.

During the initiation phase, the participating stakeholders and their stakes are identified. The key sustainability issues associated with the project are addressed and reflected into the weight allocation. The plan, including targets and actions needed, is also defined in the initiation phase and will be used as a reference point that will steer the effort to achieve the sustainability goals.

For the following life cycle stages, an iterative procedure is proposed in order to ensure continuous measurement and improvement. On the one hand, measurement will be carried out by assessing the performance based on the indicators selected within the context of TBL and the assessment criteria proposed in section 5.1 will help reduce subjectivity. On the other hand, the representation of the results in spider diagrams will facilitate easy communication and information sharing with the affected stakeholders. Focus should be given on indicators with poor performance and high weighting as they are expected to have a significant impact on the outcome. Together with the stakeholders, targeted corrective measures can be agreed to implement in the following stages. That kind of interaction would contribute towards improved performance and increase the chances for a sustainable project.

The last part of the proposed framework refers to the execution of a final assessment and knowledge management in order to keep track of the lessons learnt from the completed project and use them as input in future projects.

8. CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS

8.1 Answers to research questions

In section 1.4, the main research question was formulated and a set of four sub-questions were defined. The combined knowledge acquired from the sub-questions will provide a clear answer to the main research question (Verschuren & Doorewaard, 2010). For that purpose, the order is reversed and the answers to the sub-questions are provided first, leading up to the main question.

1) What are the performance indicators and existing frameworks for sustainability assessment within the context of TBL in the construction industry?

A thorough literature review led to the identification of performance indicators that have been developed to measure the three dimensions of sustainability. In total, a number of 24, 24 and 23 indicators were identified for the environmental, societal and economic aspect of the TBL. The large number of indicators indicates that there is no general consensus on an appropriate set of indicators that can sufficiently measure the sustainability performance of construction projects.

As far as the existing frameworks are concerned, a total number of 9 assessment frameworks for the construction industry and 4 for other industries were studied. The various frameworks studied differ in many aspects. Some frameworks provide qualitative assessments while others provide quantitative reporting with the use of complex mathematical models. Regarding the degree of coverage of the three dimensions of TBL, some frameworks are exclusively developed to assess only a single dimension while others cover all three aspects. The frameworks developed for other industries such as the supply chain and manufacturing, follow a quantitative approach and adhere to the concept of TBL, however they use very sector-specific indicators and cannot be used directly in the construction industry.

Assessment frameworks developed by private institutions were also studied in this research. These are commercial rating systems and the interested parties have to invest a certain amount of money to receive a certification which is issued by trained experts. The main conclusion from these frameworks is that they focus merely on the environmental dimension while the social and economic aspects are neglected.

2) How can we select an appropriate set of indicators that covers adequately the three dimensions of TBL and how can these indicators be utilized to create and assessment methodology?

The initial list of indicators went through a filtering process in order to form the final sets that will be used to assess construction projects. As explained in section 3.1.2, the criteria used to refine the initial pool of indicators are: Comparison with the UN global indicator framework, Variety of sources, Frequency of appearance in literature, Level of detail. The filtering process resulted in a number of 14 indicators for the environment, 15 for the society and 13 for the economy.

The final sets of indicators provided the foundation for the creation of the assessment tool. The tool provides a weighted assessment score for each one of the three dimensions of the TBL and is structured in four parts, namely: weight calculation, performance scoring, weighted assessment score calculation and visualization of results. The results are visualized in spider diagrams and bar charts

3) To what extent is the proposed methodology applicable in the construction industry and how flexible it is to be applied in projects of different nature?

The answer to this question is mainly based on the findings from the case study. The proposed methodology was critically reviewed as comprehensive with a straightforward assessment procedure and the results were easy to communicate. At the moment, integrating this assessment method into a company's management system remains questionable. On the one hand, the contractor's awareness of sustainability remains restricted in the environmental dimension and allocating extra resources would be difficult, unless it was a clear requirement set by the client. On the other hand, this model could be a useful tool to communicate information, initiatives and sustainability results with the involved stakeholders.

Regarding the applicability in different type of projects, the indicators included in the model were considered to cover sufficiently the three dimensions of sustainability and the aspects measured are found in all types of construction projects, to a certain degree. The list of indicators however, is not exhaustive. In case of specific project requirements, the model can be easily adapted by adding indicators. That was the reason why an optional project specific indicator (or more) was inititally proposed in the final list of indicators.

4) How to make a new framework that could lead to enhanced integration of construction sustainability and reduce subjectivity in the assessment procedure?

Regarding the matter of subjectivity, it was attempted to reduce the amount of subjectivity in assessments with the proposal of evaluation criteria. However, it cannot be claimed that this deficiency of the proposed tool is addressed sufficiently. The effectiveness of the proposed criteria needs to be further explored. The conceptual framework proposed in section 5.2 relies on the findings from both the literature and the case study. The continuous involvement of stakeholders in the assessment process, either by defining the weights or by being kept informed, could lead to enhanced sustainability performance and increase the chances for a sustainable project. The above statement was also adopted by the sustainability consultant during the interview as the construction works are on hold for the moment and a different approach with more involvement of the stakeholders would have better results.

The aforementioned provide the answer to the central research question, which was:

How can sustainability integration into construction projects be structured such that it leads to quantitative performance reporting on all three dimensions of Triple Bottom Line?

The studied project confirmed the argument from literature for the poor implementation of the TBL framework in the construction industry. Unless there is governmental regulation, contractors hesitate to undertake initiatives mainly due to lack of knowledge and limited resources. On the other hand, the necessity for sustainable construction practices is acknowledged and any initiatives beyond just minimum requirements could turn out to be a strategic advantage for the company.

The main research question is answered by proposing the conceptual framework with the assessment method that enhances sustainability integration into construction projects from “cradle to grave”. The framework is built upon observations from both literature and practice. The framework also attempts to connect sustainability performance with the needs of stakeholders by allowing them to participate in the assessment process and keep them involved in all life cycle stages. The proposed assessment method with the suggested scoring system of indicators produces quantitative results which are easy to communicate with the interested parties. The visualization of results in spider diagrams allows the decision makers to focus on specific indicators and initiate actions to improve performance.

The matter of subjectivity could not be addressed adequately, mainly due to the qualitative nature of certain indicators. The appointment of external consultants to perform the assessment and the proposal of the four criteria for scoring (minimum requirements, comparison with similar projects, questionnaire survey and experts judgement) are expected to lower the amount of subjectivity in the assessments.

8.2 Discussion

8.2.1 Practical contribution

The investigation of the current practices in the field of construction sustainability, through the ViA15 project, revealed that the environmental dimension prevails over the other two aspects of the TBL. With this research, awareness on the TBL framework in the construction industry is raised and construction companies are offered with a tool that allows them to consider sustainability as a multidimensional issue where all dimensions are treated equally. Moreover, this tool can be used for stakeholder management as it allows the incorporation of views and opinions of the various stakeholders, the monitoring of the project performance in the three aspects of the TBL, the planning of actions required to improve performance and the easy communication of results.

The proposed assessment tool is intended for construction companies that are involved in the design, construction and/or operation and maintenance stage. The applicability of the tool was examined in a DBFM contract which means that the contractor is involved in the project from the early stages and plays the role of both the designer and the constructor. Thus, the framework proposed in section 6.2 can be adopted by the contractor as a whole. In case the roles of the designer and the constructor are separated in a project, the assessment process with the proposed tool could be initiated by the designer, since he is involved earlier in the project, and then, the preliminary assessments together with the relevant information could be delivered to the constructor during the tender stage as it contains important information that may affect the tender price.

This issue becomes more challenging when examining the perspective of the client and whether he can adopt the proposed tool or not. The client usually creates a list of sustainability requirements based on existing regulations and predefined standards. Unquestionably, the ultimate goal of achieving sustainable development is common for the participating parties, however, the use of the proposed assessment tool as a client's requirement remains questionable due to the absence of clear assessment criteria and the limited availability of data for many aspects of sustainability. As such, the feasibility of applying the proposed assessment tool from the client's perspective needs to be further explored.

The applicability of the proposed framework is not restricted to a certain kind of projects as the indicators that formed the final list are generally applicable to every kind of construction projects. Indicators such as "indoor environmental quality" that refer to a specific type of projects were excluded but if needed, could be added very easily in the assessment process. The same applies if any other special project requirements are present as well. The tool can be easily tailored to fit the needs of the project.

Lastly, the notion of sustainable development is continuously evolving and governments and other institutions set new regulations to stimulate progress towards sustainability goals and targets. A construction company that has successfully adopted TBL principles to report sustainability results could gain a competitive advantage in the market as it will be ready for the future.

8.2.2 Scientific contribution

The problem statement as it was formulated in the introductory part of this research, referred to the poor integration of sustainability into construction practices due to the absence of a clear reporting method. The large number of performance indicators that have been developed in the past years indicate that there is no general consensus on an appropriate set of indicators. This study contributes to the scientific area of construction sustainability by filling the existing gap in literature with the proposal of an assessment method that allows for holistic evaluation of sustainability performance within the content of TBL, where all dimensions are treated equally. Moreover, simplicity, rather than complexity, was the main principle for developing the conceptual framework in order to encourage organizations to adapt a new philosophy of reporting results. The proposed framework asks for commitment from organizations and individuals to continuously monitor and improve sustainability performance and the use of complex tools and techniques was avoided.

8.2.3 Limitations

The possibility of investigating more real-life projects was explored however the investigation was restricted to only one project. The limited timeframe to conduct this research and the unwillingness of construction companies to support the author with the case study application did not allow for other projects to be examined. It is safe to consider that the findings from the case study represent adequately the current situation in infrastructure projects in the Netherlands for two reasons. Firstly, the interviewee was a sustainability consultant for the consortium of contractors and engineering companies that was realizing the project and it was clearly stated that the answers provided were on behalf of the complete team involved in the project. Secondly, from the client's perspective, the contractor was obliged to report results only for the environmental impact indicating that there is no regulation that urges companies to provide results within the context of TBL. However, generalization of findings for all types of construction projects, for instance buildings or energy projects, cannot be made safely as regulations and current practices may differ significantly from those studied.

Regarding the qualitative interviews, the original intention was to conduct them with various sustainability experts from different departments in order capture different views and opinions. Due to limited time available and unwillingness of more individuals to participate the critical review of the proposed model was made by only one sustainability expert. Therefore, the provided answers regarding the current practices and the critical review of the model could be biased by the respondent's personal opinion and need to be critically evaluated by the reader of this study.

Lastly, the quantification of certain indicators especially from the environmental and social category has proven to be a challenging task. The issue of subjectivity in the assessment procedure has not been addressed sufficiently. For that reason, the proposed model cannot be used currently as an official tool to report sustainability results but only for managing stakeholders by providing clear and transparent information on initiatives and impacts.

8.3 Recommendations for future research

This section of the report is devoted to suggest recommendations for future research on the field sustainability assessment in the construction industry.

It is argued by many scholars that sustainability is a multifaceted issue with sometimes conflicting values. Performance on certain indicators can be regarded as “communicating barrels”. Any initiative to improve performance on a specific indicator may negatively affect performance on another indicator. With that in mind, it is suggested that the interrelation between the indicators included in the assessment model needs to be further explored in order to allow practitioners to make well-informed decisions.

The sustainability expert that participated in the interview clearly stated that the team of experts involved in the project was focused exclusively on trying to meet the client’s requirements and the implementation of the proposed tool would not be possible unless it was a prerequisite. On the other hand, the interviewee claimed that undertaking sustainability initiatives is good for the company’s image and could provide a strategic advantage against its competitors. For that reason, it is recommended to conduct a cost-benefit analysis on the use of the proposed conceptual framework (which integrates the assessment method) so that the costs associated with the use of the reporting tool can be compared with the benefits gained and make a final decision on whether to adopt the assessment tool or not.

Another recommendation for researchers is to explore the possibility of standardizing the assessment process by developing evaluation rubrics for the proposed indicators. In this way, the matter of subjectivity in the assessment process will be minimized. Diverse lines of evidence will be produced and each scale of the scoring system will be connected with evaluation criteria. As a result, clear and transparent assessment will be ensured.

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Appendix A

Analytical tables for the identification of performance indicators

Table A-1: Identification of indicators (Environmental)

Environmental indicators		(Wu et al., 2018)	(Kucukvar & Tatari, 2013)	(Ding, 2008)	(Li, Gu, & Liu, 2018)	(Yu et al., 2018)	(Kamali & Hewage, 2017)	(Hakkinen, 2007)	(Moldan, Janouskova, & Hak, 2012)	(Fernandez-Sanchez & Rodriguez-Lopez, 2010)	(Stanitsas, Kirytopoulos, & Leopoulos, 2020)	(Azapagic, 2004)	(Martens & Carvalho, 2017)	(Cottafava & Ritzen, 2020)	(Ellen MacArthur Foundation, 2015)	Total
1	Adaptation and vulnerability to climate change-environment									x	x		x			3
2	Air quallity around the project	x							x			x				3
3	Application on energy saving,ecology and intelligent technology	x									x					2
4	CO2 uptake land		x													1
5	Deforestation								x							1
6	Disaster risks (quakes/floods)										x					1
7	Ecosystem/Biodiversity protection	x	x		x	x			x	x	x	x	x			9
8	Energy performance/Energy consumption	x	x	x	x	x	x			x	x		x			9
9	Material circularity													x	x	2
10	Greenhouse gas emissions	x	x		x	x	x		x	x		x				8
11	Indoor environmental quality	x		x					x							3
12	Land use	x	x													2

13	Loss of habitat			x												1
14	Material resources/ sustainable use of natural resources	x			x	x	x			x	x	x	x			8
15	Noise level/reduction	x			x	x				x		x				5
16	Pollution			x		x										2
17	Protection of water resources	x								x						2
18	Recycling of materials and water	x			x	x						x				4
19	Renewable energy	x			x	x	x			x	x	x				7
20	Site selection						x									1
21	Use of green products					x	x									2
22	Waste management	x			x	x	x			x		x				6
23	Water and waste water efficiency strategies						x					x	x			3
24	Water footprint		x		x	x			x		x					5

Table A-2: Identification of indicators (Societal)

Social indicators		(Wu et al., 2018)	(Kucukvar & Tatari, 2013)	(Ding, 2008)	(Li, Gu, & Liu, 2018)	(Yu et al., 2018)	(Kamali & Hewage, 2017)	(Hakkinen, 2007)	(Moldan, Janouskova, & Hak, 2012)	(Fernandez-Sanchez & Rodriguez-Lopez, 2010)	(Stanitsas, Kirytopoulos, & Leopoulos, 2020)	(Azapagic, 2004)	(Martens & Carvalho, 2017)	Total
1	Aesthetics/visual impact						x			x				2
2	Culture and heritage preservation					x	x							2

3	Fair sharing of benefits					x								1
4	Gender equality				x									1
5	Health, comfort and well being of occupants						x	x	x	x		x	x	6
6	Wages and benefits		x									x	x	3
7	Influence on the local economy						x						x	2
8	Leisure			x										1
9	Living environment/ Needs assessment of society-people			x			x				x			3
10	Local participation					x				x	x	x	x	5
11	Local social development						x							1
12	Local workforce				x	x								2
13	Market supply and demand	x												1
14	Occupational health and safety	x	x			x	x					x	x	6
15	Peace and justice				x								x	2
16	Percentage of community residents who must be relocated due to the project/community disturbance	x												1
17	Productivity			x										1
18	Reducing inequalities								x			x		2
19	Safety and security						x			x				2
20	Taxes		x							x				2
21	Transportation infrastructure/accessibility and amenities				x	x				x				3
22	Use of regional materials									x		x		2
23	User and owner satisfaction	x					x	x						3
24	Work created throughout the project cycle	x		x								x		3

Table A-3: Identification of indicators (Economic)

	Economic indicators	(Wu et al., 2018)	(Kucukvar & Tatari, 2013)	(Ding, 2008)	(Li, Gu, & Liu, 2018)	(Kamali & Hewage, 2017)	(Hakkinen, 2007)	(Fernandez-Sanchez & Rodriguez-Lopez, 2010)	(Stanitsas, Kirytopoulos, & Leopoulos, 2020)	(Ihuah, Kakulu, & Eaton, 2014)	(Toor & Ogunlana, 2008)	(Azapagic, 2004)	(Saez-Martinez et al., 2016)	(Gudiene, Banaitis, & Banaitiene, 2013)	(Liu, Skibniewski, & Wang, 2016)	(Martens & Carvalho, 2017)	(Lee et al., 2018)	(Tabish & Jha, 2011)	(Brauer, 2013)	(Fortune & White, 2006)	Total
1	Innovation management/new product development						x		x		x		x	x	x	x					7
2	Cost management plan	x			x			x	x			x				x					6
3	Developing an efficient risk management plan								x	x				x	x		x			x	6
4	Financial performance			x					x			x		x		x					5
5	Effective project control								x	x	x			x						x	5
6	Efficient allocation of resources								x		x							x		x	4
7	Contribution to GDP		x									x				x					3

8	Investment amount				x	x						x									3
9	Abbility to pay and affordability								x	x				x							3
10	Business ethics								x							x			x		3
11	Effective change management strategy								x		x									x	3
12	Life/endurance of construction and design	x				x															2
13	Economic and political stability								x											x	2
14	Design and Construction time					x															1
15	Economic diversity in project affected areas	x																			1
16	Flexibility					x															1
17	Gross Operating Surplus		x																		1
18	Imports		x																		1
19	Integrated management					x															1
20	Percentage of population receiving external benefits in project affected areas	x																			1
21	Readjustment for new business environment						x														1
22	Supply chain collaboration								x												1
23	Project output emphasis								x												1

Appendix B

Analytical comparison between indicators identified in literature and the UNSDGs and targets

Table B-1: Cross-comparison between literature and UN global indicator framework (Environment)

	Environmental sustainability indicator	**SDGs and targets** (IAEG-SDGs, 2017)
1	Adaptation and vulnerability to climate change-environment	**13.1** Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries **13.2** Integrate climate change measures into national policies, strategies and planning
2	Air quallity around the project	**3.9** By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination
3	Application on energy saving,ecology and intelligent technology	**7.a** By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology **7.b** By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support **17.7** Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed **17.8** Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology
4	CO2 uptake land	
5	Deforestation	**6.6** By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes **15.2** By 2020, promote the implementation of sustainable management of all types of forests, halt

		deforestation, restore degraded forests and substantially increase afforestation and reforestation globally **15.b** Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation
6	Disaster risks (quakes/floods)	**1.5** By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters **11.5** By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations **11.b** By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels **13.1** Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries
7	Ecosystem/Biodiversity protection	**6.6** By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes **14.2** By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans **14.5** By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information **14.c** Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in the United Nations Convention on the Law of the Sea, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of “The future we want” **15.1** By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland

		freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements **15.2** By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally **15.3** By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world **15.4** By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development **15.5** Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species **15.7** Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products **15.9** By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts **15.a** Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems
8	Energy performance/Energy consumption	**7.3** By 2030, double the global rate of improvement in energy efficiency
9	Environmental impact/ecological footprint	**11.6** By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management **14.3** Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels
10	Greenhouse gas emissions	**9.4** By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities **13.2** Integrate climate change measures into national policies, strategies and planning
11	Indoor environmental quality	
12	Land use	
13	Loss of habitat	**6.6** By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands,

		rivers, aquifers and lakes **15.5** Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species
14	Material resources	**8.4** Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead **12.2** By 2030, achieve the sustainable management and efficient use of natural resources
15	Noise level/reduction	
16	Pollution	**3.9** By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination **14.1** By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution
17	Protection of water resources	**3.9** By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination **6.1** By 2030, achieve universal and equitable access to safe and affordable drinking water for all **6.6** By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes **14.1** By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution
18	Recycling of materials and water	**6.a** By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies **12.5** By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse
19	Renewable energy	**7.2** By 2030, increase substantially the share of renewable energy in the global energy mix **7.a** By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology **7.b** By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing

		States and landlocked developing countries, in accordance with their respective programmes of support **12.a** Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production
20	Site selection	
21	Use of green products	
22	Waste management	**12.4** By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment **12.5** By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse
23	Water and waste water efficiency strategies	**6.3** By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally **6.4** By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity **6.5** By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate **6.a** By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies
24	Water footprint	

Table B-2: Cross-comparison between literature and UN global indicator framework (Society)

No.	**Social sustainability indicator**	**SDGs and targets** (IAEG-SDGs, 2017)
1	Aesthetics/visual impact	
2	Culture and heritage preservation	**11.4** Strengthen efforts to protect and safeguard the world’s cultural and natural heritage
3	Fair sharing of benefits	**1.4** By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other

		forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance **8.5** By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value **9.3** Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets **10.4** Adopt policies, especially fiscal, wage and social protection policies, and progressively achieve greater equality **15.6** Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed
4	Gender equality	**5.1** End all forms of discrimination against all women and girls everywhere **5.5** Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life **5.a** Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws **5.c** Adopt and strengthen sound policies and enforceable legislation for the promotion of gender equality and the empowerment of all women and girls at all levels **8.5** By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value
5	Health, comfort and well being of occupants	**3.6** By 2020, halve the number of global deaths and injuries from road traffic accidents **3.9** By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination
6	Wages and benefits	**1.1** By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day **1.2** By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions **8.5** By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value

		10.1 By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average
7	Influence on the local economy	**1.1** By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day **1.2** By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions
8	Leisure	
9	Living environment	**11.1** By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums **11.7** By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities
10	Local participation	**6.b** Support and strengthen the participation of local communities in improving water and sanitation management **11.3** By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries **16.7** Ensure responsive, inclusive, participatory and representative decision-making at all levels
11	Local social development	**8.6** By 2020, substantially reduce the proportion of youth not in employment, education or training
12	Local workforce	
13	Market supply and demand	
14	Occupational health and safety	**8.8** Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment
15	Peace and justice	**1.3** Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable **8.7** Take immediate and effective measures to eradicate forced labour, end modern slavery and human trafficking and secure the prohibition and elimination of the worst forms of child labour, including recruitment and use of child soldiers, and by 2025 end child labour in all its forms **16.3** Promote the rule of law at the national and international levels and ensure equal access to justice for all **16.a** Strengthen relevant national institutions, including through international cooperation, for building capacity at all levels, in particular in developing countries, to prevent violence and combat terrorism and

		crime
16	Percentage of community residents who must be relocated due to the project/community disturbance	
17	Productivity	
18	Reducing inequalities	**5.1** End all forms of discrimination against all women and girls everywhere **5.5** Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life **5.a** Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws **5.c** Adopt and strengthen sound policies and enforceable legislation for the promotion of gender equality and the empowerment of all women and girls at all levels **10.1** By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average **10.2** By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status **10.3** Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action in this regard **10.4** Adopt policies, especially fiscal, wage and social protection policies, and progressively achieve greater equality **16.b** Promote and enforce non-discriminatory laws and policies for sustainable development
19	Safety and security	**1.5** By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters **3.6** By 2020, halve the number of global deaths and injuries from road traffic accidents **11.5** By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable

		situations **11.7** By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities **16.1** Significantly reduce all forms of violence and related death rates everywhere **16.2** End abuse, exploitation, trafficking and all forms of violence against and torture of children **16.a** Strengthen relevant national institutions, including through international cooperation, for building capacity at all levels, in particular in developing countries, to prevent violence and combat terrorism and crime
20	Taxes	
21	Transportation infrastructure/accessibility and amenities	**1.4** By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance **9.1** Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all **11.2** By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons
22	Use of regional materials	**11.c** Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials
23	User and owner satisfaction	
24	Work created throughout the project cycle	**1.1** By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day **1.2** By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions **8.3** Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services **8.5** By 2030, achieve full and productive employment and decent work for all women and men, including

		for young people and persons with disabilities, and equal pay for work of equal value **9.2** Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries

Table B-3: Cross-comparison between literature and UN global indicator framework (Economy)

No.	Economic sustainability indicator	SDGs and targets (IAEG-SDGs, 2017)
1	Contribution to GDP	**1.5** By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters **8.1** Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries **8.2** Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors **9.2** Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries **11.5** By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations
2	Cost control	
3	Cost-effectiveness	
4	Design and Construction costs	
5	Design and Construction time	
6	Economic diversity in project affected areas	

7	End of life costs /Design for disassembly	
8	Exploitation of new technological challenges	**9.5** Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending
9	Flexibility	
10	Gross Operating Surplus	
11	Imports	
12	Integrated management	
13	Investment amount	
14	Labour cost	
15	Land acquisition cost	
16	Life cycle cost	
17	Life/endurance of construction and design	
18	Maintenance and renovation	
19	Material cost	
20	Operational costs	
21	Percentage of population receiving external benefits in project affected areas	
22	Plant and equipment cost	
23	Readjustment for new business environment	
24	Revenue	

Appendix C

Extended tables indicators, short descriptions and indicative references

Table C-1 Final set of indicators including description and references (Environment)

Code	Environmental indicators	Description	Indicative references
En1	Adaptation and vulnerability to climate change-environment	It refers to development of a future-proof strategy to build resilience against climate change	(Fernandez-Sanchez & Rodriguez-Lopez, 2010; Stanitsas, Kirytopoulos, & Leopoulos, 2020)
En2	Air quality around the project	The quality level of air surrounding the project during construction, operation and decommissioning	(Wu et al., 2018; Azapagic, 2004)
En3	Application on energy saving, ecology and intelligent technology	The use of modern technology to ensure the lifetime sustainability of the project.	(Wu et al., 2018; Stanitsas, Kirytopoulos, & Leopoulos, 2020)
En4	Disaster risks	Refers to the resilience of the project against disasters	(Stanitsas, Kirytopoulos, & Leopoulos, 2020)
En5	Ecosystem/Biodiversity protection	It concerns the protection and restoration of all environmental ecosystems	(Kucukvar & Tatari, 2013; Li, Gu, & Liu, 2018)
En6	Energy performance	It refers to efficient production, use, distribution, and transmission of energy to provide products and services.	(Ding, 2008; Yu et al., 2018)
En7	Greenhouse gas emissions	Amount of greenhouse gases emissions that contribute to global warming	(Yu et al., 2018; Wu et al., 2018; Moldan, Janouskova & Hak, 2012)
En8	Sustainable use of material resources	It refers to minimizing resource usage, primary material input and output, waste recovery and disposal operations	(Stanitsas, Kirytopoulos, & Leopoulos, 2020; Azapagic, 2004)
En9	Noise level/reduction	Refers to the mitigation measure adopted to lower the level of nuisance to neighbouring communities related with the project during construction, operation and decomissioning stages	(Wu et al., 2018; Li, Gu & Liu, 2018)
En10	Renewable energy	It refers to the	(Stanitsas,

		environmentally friendly selection of the primary energy sources that contributes towards the effective operation of the project	Kirytopoulos, & Leopoulos, 2020; Azapagic, 2004)
En11	Waste management	Refers to the existence of a plan to minimize waste production to avoid pollution and promote recycle and reusal of components	(Wu et al., 2018; Li, Gu & Liu, 2018)
En12	Water and waste water efficiency strategies	It refers to water quality during the construction phase and after the completion of the project, reduction of liquid waste, risks on water pollution	(Kamali & Hewage, 2017; Martens & Carvalho, 2017)
En13	Material circularity	Refers to the amount of raw material required, the utility of the product and and amount of unrecoverable waste generated	(Ellen MacArthur Foundation, 2015; Cottafava & Ritzen, 2020)
En14	Project specific (optional)	Project specific indicator according to the project's peculiarities	

Table C-2 Final set of indicators including description and references (Society)

Code	**Social indicators**	**Description**	**Indicative references**
Soc1	Aesthetics/visual impact	The degree to which the project is designed to reduce eye strain and provide visual comfort	(Kamali & Hewage, 2017; Fernandez-Sanchez & Rodriguez-Lopez, 2010)
Soc2	Culture and heritage preservation	Strengthen efforts to protect and safeguard the world's cultural and natural heritage	(Yu et al., 2018; Kamali & Hewage, 2017)
Soc3	Fair sharing of benefits	Refers to the fair distribution of economic and other benefit deriving from the project	(Yu et al., 2018)
Soc4	Health, comfort and well-being of occupants	The approach to ensure the well-being of users of the project	(Hakkinen, 2007; Moldan, Janouskova & Hak, 2012)
Soc5	Wages and benefits	Refers to salaries and	(Kucukvar & Tatari,

		benefits provided by direct and indirect employment	2013; Kamali & Hewage, 2017)
Soc6	Living environment	The social apprehension of needs for desired living conditions.	(Ding, 2008; Kamali & Hewage, 2017)
Soc7	Local participation	The social apprehension of needs and interaction with the project stakeholders to the overall benefit of the project,	(Yu et al., 2018; Martens & Carvalho, 2017)
Soc8	Local social development	The level of commitment to human capital demonstrated through investment in employee skills development	(Kamali & Hewage, 2017)
Soc9	Occupational health and safety	The commitment to minimize work related injuries and fatalities	(Wu et al., 2018; Wu et al., 2018)
Soc10	Reducing inequalities	End all forms of discriminations and achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value	(Moldan, Janouskova & Hak, 2012; Azapagic, 2004)
Soc11	Safety and security	Reduce the exposure to dangerous and unsafe situations in the overall project environment	(Kamali & Hewage, 2017; Fernandez-Sanchez & Rodriguez-Lopez, 2010)
Soc12	Transportation infrastructure/accessibility and amenities	Quality, reliable, sustainable and resilient infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all	(Li, Gu & Liu, 2018; Yu et al., 2018)
Soc13	Use of regional materials	Promote the use of regional materials to support suppliers from the project-affected area and minimize transportation costs,time and distance	(Fernandez-Sanchez & Rodriguez-Lopez, 2010)
Soc14	Work created throughout the project cycle	Contribution to direct employment to community and national economy	(Wu et al.,2018; Ding 2008)
Soc15	Project specific (optional)	Project specific indicator according to the project's peculiarities	

Table C-3 Final set of indicators including description and references (Economy)

Code	Economic indicators	Description	Indicative references
Eco1	Innovation management/new product development	It refers to product, process, and organizational innovation. Innovation management practices come through research and development, productivity, and flexibility.	(Hakkinen, 2007; Stanitsas, Kirytopoulos & Leopoulos, 2020)
Eco2	Cost management plan	It concerns the process of planning and controlling the cost associated with the resources of a project and the other costs	(Wu et al., 2018; Martens & Carvalho, 2017)
Eco3	Developing an efficient risk management plan	It is all about the variables that can affect the project's progress and outcome, both internally and externally, taking into consideration uncertainty	(Stanitsas, Kirytopoulos & Leopoulos, 2020; Ihuah, Kakulu & Eaton, 2014)
Eco4	Financial performance	Objective measure that concerns the return on investments, the creditworthiness, the viability, and the cash flow of a project	(Ding, 2008; Stanitsas, Kirytopoulos & Leopoulos, 2020)
Eco5	Effective project control	Effective Project Control concerns the data gathering for effective time management, risk management, cost management, value management, document control, supplier performance and reporting	(Ihuah, Kakulu & Eaton, 2014; Toor & Ogunlana, 2008)
Eco6	Efficient allocation of resources	It refers to the distribution of inputs such that the resources will be efficiently utilized	(Tabish & Jha, 2011; Fortune & White, 2006)
Eco7	Contribution to GDP	Importance for and contribution to the national economies (and wealth)	(Kucukvar and Tatari, 2013); Azapagic, 2004)
Eco8	Investment amount	Total value of the capital employed, including plants, infrastructure, working capital etc	(Li, Gu & Liu, 2018; Kamali & Hewage, 2017)
Eco9	Abbility to pay and affordability	It refers to the capacity to pay for building, operating and	(Stanitsas, Kirytopoulos &

		maintaining the project.	Leopoulos, 2020; Ihuah, Kakulu & Eaton, 2014)
Eco10	Business ethics	It examines moral/ethical problems that may result from trading, affiliation with competition, and governmental obligations	(Brauer, 2013; Martens & Carvalho, 2017)
Eco11	Effective change management strategy	The process that can help facilitate change and make the transition easier for the project	(Toor & Ogunlana, 2008; Fortune & White, 2006)
Eco12	Lifetime of construction and design	Refers to the service life of constructed asset	(Wu et al.,2018; Kamali & Hewage, 2017)
Eco13	Project specific (optional)	Project specific indicator according to the project's peculiarities	

Appendix D

Importance of indicators in the ViA15 project (Answers provided by the interviewee)

Please state your position/role in the project	Sustainability consultant

GENERAL INSTRUCTION

In the next sheet, you will find a list of sustainability indicators (14 for Environment, 14 for Society and 13 for Economy). Based on your experience and according to the characteristics of the given project (Via15), please rate the importance of each indicator on a scale from 1 το 5 (see explanation below).

Importance scale	
1	Unimportant
2	Low importance
3	Moderately important
4	Very important
5	Extremely important

	Code	Indicator	Definition	Importance (1-5)
ENVIRONMENT	En1	Adaptation and vulnerability to climate change	It refers to development of a future-proof strategy to build resilience against climate change	
	En2	Air quality around the project	The quality level of air surrounding the project during construction, operation and decommissioning	2
	En3	Application on energy saving, ecology and intelligent technol	The use of modern technology to ensure lifetime sustainability of the project.	2
	En4	Disaster risks	Refers to the resilience of the project against disasters (hurricanes, earthquakes, etc.)	2
	En5	Ecosystem/Biodiversity protection	It concerns the protection and restoration of all environmental ecosystems	5
	En6	Energy performance	It refers to efficient production, use, distribution, and transmission of energy to provide products and services.	5
	En7	Greenhouse gas emissions	Amount of greenhouse gases emissions that contribute to global warming	5
	En8	Sustainable use of material resources	It refers to minimizing resource usage, primary material input and output, waste recovery and disposal operations	3
	En9	Noise level/reduction	communities related with the project during construction, operation and decommissioning stages	2
	En10	Renewable energy	It refers to the environmentally friendly selection of the primary energy sources that contributes towards the effective operation of the project	2
	En11	Waste management	Refers to the existence of an action plan to minimize waste production to avoid pollution and promote recycle and reusal of components	
	En12	Water and waste water efficiency strategies	It refers to water quality during the construction phase and after the completion of the project, reduction of liquid waste, risks on water	
	En13	Material circularity	Refers to the amount of raw material required, the utility of the product and and amount of unrecoverable waste generated	3
	En14	Project specific (optional)	Project specific indicator according to the project's peculiarities	

5= client requirement

3= indirect effect on MKI

2= project requirement

	Code	Indicator		
SOCIETY	Soc1	Aesthetics/Visual impact	The degree to which the project is designed to reduce eye strain and provide visual comfort	
	Soc2	Culture and heritage preservation	Strengthen efforts to protect and safeguard the world's cultural and natural heritage	
	Soc3	Fair sharing of benefits	Refers to the fair distribution of economic and other benefits deriving from the project	
	Soc4	Health, comfort and well-being of occupants	The approach to ensure the well-being of users of the project	2
	Soc5	Wages and benefits	Refers to salaries and benefits provided by direct and indirect employment	
	Soc6	Living environment	The social apprehension of needs for desired living conditions.	
	Soc7	Local participation	The social apprehension of needs and interaction with the project stakeholders to the overall benefit of the project	2
	Soc8	Local social development	The level of commitment to human capital demonstrated through investment in employee skills development	2
	Soc9	Occupational health and safety	The commitment to minimize work related injuries and fatalities	2
	Soc10	Reducing inequalities	End all forms of discriminations and achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value	
	Soc11	Safety and security	Reduce the exposure to dangerous and unsafe situations in the overall project environment	2
	Soc12	Transportation infrastructure/accessibility and amenities	Quality, reliable, sustainable and resilient infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all	2
	Soc13	Use of regional materials	Promote the use of regional materials to support suppliers from the project-affected area and minimize transportation costs,time and distance	3
	Soc14	Work created throughout the project cycle/employment	Contribution to direct employment to community and national economy	2
	Soc15	Project specific (optional)	Project specific indicator according to the project's peculiarities	

	Code	Indicator		
ECONOMY	Eco1	Innovation management	It refers to product, process, and organizational innovation. Innovation management practices come through research and development, productivity, and flexibility.	
	Eco2	Cost management plan	It concerns the process of planning and controlling the cost associated with the resources of a project and the other costs	
	Eco3	Developing an efficient risk management plan	It is all about the variables that can affect the project's progress and outcome, both internally and externally, taking into consideration uncertainty	
	Eco4	Financial performance	Objective measure that concerns the return on investments, the creditworthiness, the viability, and the cash flow of a project	
	Eco5	Effective project control	Effective Project Control concerns the data gathering for effective time management, risk management, cost management, value management, document control, supplier performance and reporting	
	Eco6	Efficient allocation of resources	It refers to the distribution of inputs such that the resources will be efficiently utilized	
	Eco7	Contribution to GDP	Importance for and contribution to the national economies (and wealth)	
	Eco8	Investment amount	Total value of the capital employed, including plants, infrastructure, working capital etc	
	Eco9	Ability to pay and affordability	It refers to the capacity to pay for building, operating and maintaining the project.	
	Eco10	Business ethics	It examines moral/ethical problems that may result from trading, affiliation with competition, and governmental obligations	
	Eco11	Effective change management strategy	The process that can help facilitate change and make the transition easier for the project	
	Eco12	Lifetime of construction and design	Refers to the service life of constructed asset	
	Eco13	Economic and political stability	Economic growth and political stability are interconnected. An unstable political environment impacts investment and increases the risk.	
	Eco14	Project specific (optional)	Project specific indicator according to the project's peculiarities	