Master Thesis

Enhancing Business Network Model with Environmental Assessment

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PREFACE

In 2022, I made the decision to return to academic life after a fulfilling career, embarking on a journey that brought both significant challenges and rewarding achievements. My return was driven by my desire to further my understanding of the intricate relationship between technology and business strategy, leading me to pursue a study in Business Information Technology.

The concept of sustainable business practices has always fascinated me, especially finding the right balance between economic growth and protecting the environment. Then I came across Dr. Ir. M.J. Van Sinderen, who introduced me to the topic of business network sustainability. This area of study resonated profoundly with my academic and professional aspirations, as it offers the perfect intersection of my interests in sustainability, technology, and business strategy.

I wish to express my heartfelt gratitude to all those who supported me throughout the completion of this master's thesis. My deepest appreciation is extended to my thesis supervisors, Dr. Ir. M.J. Van Sinderen and Dr. A. Abhishta, whose expert guidance and insightful feedback were instrumental in shaping this research. Their support not only enhanced the quality of my work but also pushed me to expand my thinking and explore new perspectives.

I express sincere gratitude to my colleagues at PT PLN and ICON+ for their invaluable contributions to the development of this study, particularly the case study they provided. I also extend my thanks to the participants and experts whose insightful contributions significantly enriched the depth and breadth of my research, thus confirming its relevance and applicability.

I would like to express my sincere gratitude to my family, friends, and fellow students in the BIT program and the Indonesian cohort. Your unwavering support and encouragement have been the cornerstone of my journey. Your presence during both challenging and triumphant moments has made this experience deeply meaningful and more manageable. A special thanks to my peers in the Indonesian 2022 cohort for their invaluable support, especially during the toughest times. Your companionship and understanding provided strength when I needed it the most.

I am deeply grateful to the Ministry of Communications and Informatics of Indonesia for their grant, which has made this academic endeavour possible. I also want to express my sincere gratitude to PT PLN for providing me with the opportunity and continuous support to pursue this academic goal.

Above all, my utmost gratitude is to Allah SWT, whose divine guidance and blessings have been my constant source of strength, helping me navigate the complexities of this journey with resilience and faith.

Enschede, August 2024
Nisa Azmi D

ABSTRACT

In response to evolving business ecosystem dynamics, companies are increasingly compelled to factor in environmental considerations alongside financial objectives, driven by the demands of customers, regulators, and investors. However, businesses seeking to integrate environmental considerations into their operations often lack comprehensive tools to assess both economic and environmental impacts. This study aims to address this gap by developing a method for evaluating these dual aspects.
Leveraging design science research methodology, the study commences with problem identification and a literature review to explore existing tools. Subsequently, the new method combines e3value for economic assessment and Life Cycle Assessment (LCA) for evaluating environmental impact in the treatment design phase. To demonstrate its viability, this method is applied in a case study of a solar power plant business.
Expert validation of the framework indicates that it provides moderate to high utility for practitioners aiming to reconcile economic growth with environmental responsibility. While some implementation challenges were noted, most practitioners found the framework valuable for identifying opportunities and informing decision-making. Overall, the mixed but generally positive feedback suggests that while the framework holds significant promise, further refinement and support are required to enhance its usability and implementation.

Keywords: Business Network Model, Environmental Impact Assessment, E3value, LCA.

ABBREVIATION LIST

BM	Business Model
BM-LCA	Business Model - Life Cycle Assessment
DVD	Dynamic Value Description
EPC	Engineering, Procurement, and Construction
EEEM	Ecological Economic Evaluation Method
ESG	Environmental, Social and Governance
GHG	Greenhouse Gas Emission
IUPTLU	Business Permit for General Electricity Supply
Kwh	Kilowatt Hour
Kwp	Kilowatt Peak
LCA	Life Cycle Assessment
LCCA	Life Cycle Costing Analysis
LCIA	Life Cycle Impact Analysis
LCA-NPV	Life Cycle Assessment - Net Present Value
NPV	Net Present Value
PLN	Indonesian Public Electricity Company
PV	Photovoltaics
ROI	Return of Investment
SEAM	Systemic Enterprise Architecture Method

CONTENTS

1 INTRODUCTION

The upcoming chapter will offer an overview of the research, including its background and the rationale behind the undertaken research, followed by the research questions and objectives and the methodology employed in the study.

1.1 Background

The financial aspect is considered essential for all kinds of businesses, regardless of their stage of development. The primary goal is to drive profitability and ensure sustainable financial health. Startups often prioritise product development, customer acquisition, and healthy cash flow. Established companies often prioritise forming partnerships for innovation to maximise profits and minimise operational costs. They tend to focus on factors related to monetary and economic benefits over environmental issues.

Environmental concerns have become increasingly important in recent years. Governments are implementing policies and regulations related to the environment, such as the European Commission's aim to achieve climate neutrality in the EU by 2050[3]. Furthermore, business investors are considering the environmental impact in their decision-making process. According to a survey conducted by PwC, investors prioritise reducing greenhouse gas emissions as a key factor for businesses to address[55]. McKinsey also emphasises that numerous investors incorporate Environmental, Social and Governance (ESG) criteria into their investment approaches[26].

There is a growing emphasis on environmentally sustainable products, not only from businesses and investors but also from consumers. According to a 2023 survey by NielsenIQ, 66% of respondents consider sustainability when making a purchase[45]. In addition, McKinsey's research shows that products with ESG-related claims have experienced significant sales growth[4]. The World Economic Forum also highlights that 65% of consumers are making sustainable purchasing decisions to support healthier and more environmentally friendly lifestyles[5].

Stakeholders' increasing emphasis on environmental aspects is evident in today's business environment. It is essential for businesses to integrate environmental considerations into their strategy and operations. This trend shows that focusing on environmental aspects can provide a competitive advantage by attracting investors and customers and enhancing brand reputation. In addition, a study by Friede et al. found that companies that incorporate ESG do not sacrifice their equity return; instead, they have a positive return[25]. These factors highlight the importance of not solely prioritising financial value, but also considering the environmental impact of business activities.

1.2 Terminology

1.2.1 Business Model and Value Network

A business model outlines how an organisation generates, delivers, and captures value, encompassing nine essential building blocks: Customer Segments, Value Propositions, Channels, Customer Relationships, Revenue Streams, Key Resources, Key Activities, Key Partnerships, and Cost Structure[39, 49]. Traditionally, business models focus on a single business entity.

Value networks focus on a group of interconnected organisations that collaborate to achieve a common goal[18]. In today's business environment, organisations operate within ecosystems involving various stakeholders. Creating value has become a complex process due to these intricacies, involving multiple parties. Business network models have been developed to navigate this complexity. These frameworks emphasise the value flows between different entities within a business ecosystem, aiming to visualise, analyse, and optimise the intricate web of relationships and exchanges that characterise modern business environments.

1.2.2 Environment Impact Assessment for Business Sustainability

Environmental impact assessment is a thorough process that involves analysing the potential environmental effects associated with a product, project, or activity throughout its entire life cycle. This includes assessing a wide range of factors, such as the impact on air and water quality, the amount of resources used, and the overall sustainability of the environment. The assessment is designed to make sure that those making decisions take into account the environmental effects when determining whether to move forward with a project.

In today's business landscape, companies are under pressure to demonstrate their commitment to environmental sustainability. The incorporation of environmental impact assessments is essential for companies striving to operate in a sustainable manner. Identifying and evaluating the potential environmental impacts of a proposed project before its commencement enables companies to make informed decisions that take environmental factors into account. Incorporating it into the decision-making process is critical for integrating environmental considerations, resulting in more sustainable outcomes that benefit the environment, the company, and society at large.

1.3 Motivation

When starting a new business, developing a product, or undertaking a project, it is important to carefully assess the economic factors. Economic viability, such as cost analysis and revenue projections, are critical considerations at the strategic level. Various approaches that incorporate economic benefits exist at the strategic level. One example is Michael Porter's[53] strategy for competitive advantage, which highlights the significance of economic value and competitive positioning in early-stage strategic planning for businesses. Additionally, methods such as the Business Model Canvas by Osterwalder and Pigneur[49] focus on value creation, cost structure, and revenue generation, providing a comprehensive approach to evaluating and developing a viable business model which helps visualise several aspects of a business, ensuring that economic variables are considered and aligned with the overall strategy.

To tackle the unique challenges associated with evaluating economic performance within business networks, specialised frameworks have been developed. The business network model plays a pivotal role in modern business strategy. This model acknowledges that businesses do not operate independently but rather as part of a complex network of interconnected entities, including suppliers, partners, customers, and other stakeholders. The e3value methodology, introduced by Gordijn, integrates IT systems analysis with a business-focused economic value perspective[30]. It emphasises the interaction of actors within a network and their value flows, enabling the development and exchange of economic value among stakeholders. By delineating these relationships, businesses can gain a deeper understanding of the flow of value within the network. Additionally, it provides a way to assess the exchange of economic value both qualitatively and quantitatively.

In a business landscape, environmental assessments are primarily conducted during the operational phase of a project or activity. These assessments are aimed at evaluating the impact of ongoing operations on the environment and identifying any potential issues that may arise. Evidence from Greenpeace's report highlights that major cloud providers initially focus on rapid expansion and financial gain[15]. Additionally, the report that examines energy usage in U.S. data centres notes that early economic considerations, such as operational efficiency and cost reduction, were primary drivers in the planning and design phases, while environmental impacts and energy efficiency were often addressed later as secondary concerns[61].

When there is a disconnect or delay between conducting economic feasibility and environmental assessments, it can pose significant challenges for a business, potentially leading to increased costs and reputation damage. For instance, if a cloud service company prioritises the economic aspect of the expansion of its data centre without considering the environmental implications, a subsequent environmental assessment may uncover limited access to renewable energy sources at the selected location. This oversight could result in higher carbon emissions and operational costs stemming from reliance on non-renewable energy sources, leading to long-term financial implications, a larger carbon footprint, and potential regulatory hurdles.

It is of utmost importance to conduct a comprehensive assessment of the potential environmental repercussions and financial viability of a project during its initial stages. This thorough evaluation is critical for gaining insight into the possible trade-offs between environmental impact and financial aspects. The information obtained from this analysis is invaluable for enabling business stakeholders to make well-informed decisions while also playing a crucial role in enhancing risk management strategies.

Businesses are increasingly recognising the importance of environmental considerations, prompting a significant shift in their mindset. There is a gradual but noticeable shift towards environmental consciousness, with businesses not only promoting corporate social responsibility initiatives that align with their environmental concerns but also actively integrating green or circular economy principles into their operations. This shift reflects a growing awareness of the need to prioritise environmental sustainability alongside traditional business objectives.

Many companies are now integrating environmental considerations into their operations. Volkswagen (VW) is a great example, as they are shifting from a traditional automotive manufacturer to a mobility company, as stated in their ESG report for 2022[2]. Their goal is to reduce carbon emissions and resource consumption while maintaining a sustainable and profitable business model. This shift involves a complete transformation of their business model, including new revenue streams such as Electric Vehicle(EV) sales, battery leasing, charging services, and digital services related to EVs. VW has made substantial investments in research and development for EV technology, battery manufacturing, and charging infrastructure. They have also conducted a comprehensive analysis of the cost savings from reduced fuel and maintenance expenses over the vehicle's life cycle, as well as the environmental impacts at every stage, from raw material extraction to end-of-life recycling.

IKEA has set a commendable example by embracing circular economy principles. Their approach involves encouraging customers to reuse and prolong the lifespan of their furniture. In addition, IKEA's product designs prioritise closed-loop lifecycles by emphasising durability, repairability, and recyclability[11]. Furthermore, the company is dedicated to using renewable energy and prioritising sustainable sourcing throughout its business operations.

The experiences of Volkswagen and IKEA illustrate that incorporating environmental considerations into business operations can transform a company's entire business model, not just its operational practices. These examples demonstrate that integrating environmental aspects into business strategies can lead to holistic changes, driving innovation and sustainability. Companies must ensure that their entire supply chain and energy-sourcing practices align with their environmental goals.

Traditional strategic methods like Porter's Competitive Advantage and the Business Model Canvas qualitatively highlight changes or new revenue models, focusing primarily on economic value and competitive positioning. Similarly, the business network model emphasises value flow and economic interconnections among stakeholders. However, these methods often fall short of providing insights into environmental impacts and cannot adequately assess the trade-offs between economic and environmental factors.

While environmental impact assessment methods exist, their integration with traditional business strategic methods is not obvious or straightforward. Environmental assessments are typically conducted separately from business strategy analysis, creating a disconnect that makes it challenging to seamlessly incorporate environmental considerations into strategic planning. This limitation hinders businesses aiming for both economic success and environmental sustainability.

Integrating environmental impact assessments into strategic planning is crucial for companies with broader environmental goals. This integration ensures that their strategies are both economically viable and environmentally responsible. Providing an integrated approach, businesses can better navigate the complexities of modern ecosystems, balancing profitability with sustainability and fostering long-term success.

1.4 Problem Statement & Significance of Study

Economic factors often take precedence in decision-making processes, sometimes overshadowing the importance of environmental sustainability. However, in today's business environment, there is a growing focus on the environmental impact of corporate activities. It is no longer adequate for businesses to focus solely on profitability; they must also ensure that their operations are carried out in an environmentally sustainable manner. This dual emphasis necessitates a thorough and meticulous approach, evaluating both the economic feasibility and adherence to environmental best practices and regulations.

It can be risky to postpone environmental assessments until economic considerations have been addressed, as this could result in significant financial and reputational losses. Making strategic decisions based solely on economic factors without considering environmental impacts at the same time may require expensive revisions later on. Traditional business models often provide detailed analyses of revenue generation and cost structures but

frequently neglect to assess environmental impact, creating a significant imbalance that hinders long-term sustainable development.
As a result, there is a growing need for an integrated approach that simultaneously evaluates both the economic and environmental aspects of business models. A holistic assessment is essential to ensure that businesses can achieve sustainable growth while fulfilling their environmental responsibilities. This involves evaluating economic factors such as revenue and profitability alongside environmental factors like resource usage, waste management, and emissions. The ultimate goal is to strike a balance where businesses can thrive economically while minimising their environmental footprint, contributing to a more sustainable future. This thesis aims to explore and develop a method for a balanced approach to evaluating both economic and environmental factors, thus ensuring that businesses can grow sustainably while meeting their environmental obligations.

1.5 Research Questions and Objectives

Based on the stated problem statement, a holistic approach to assessing both economic and environmental aspects is needed. This study aims to develop a comprehensive business value modelling that assesses economic values and environmental impact. This research encompasses the main research question, sub-questions (SQ), and objectives as follows:

Main Research Question:

How can a business value model be developed and refined to assess economic value and environmental impact based on the existing method(s) to assist businesses in making informed decisions that effectively balance economic growth with environmental stewardship?

Sub-Research Question:

SQ1 What is the state of the art in environmental impacts assessment methodologies and business network models?

The aim of this research question is to investigate the current methodologies in environmental impact assessment and business network models. The objective is to identify method and frameworks that offer comprehensive assessments of the environment, economic aspects, and any combined methods. Additionally, this study aims to conduct a gap analysis of the existing literature.

SQ2 How can the business network model and environmental impact be combined to assess both aspects in a unified framework?

This research question aims to design and develop a framework that combines the business network model with environmental impact assessment using existing methods. The goal is to allow for a comprehensive evaluation of both the economic and environmental aspects of business operations in the early stage of business. This framework will aid decision-makers in identifying and analysing stakeholders, relationships, and value flows while integrating key environmental indicators and data across the network.

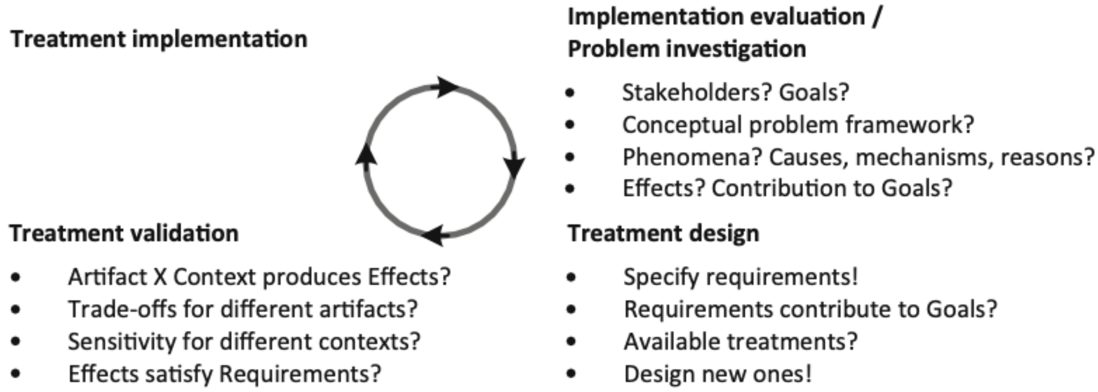


Figure 1.1: Design Science Research Methodology [74]

SQ3 To what extent does the designed framework assist practitioners in making informed decisions to balance economic growth with environmental stewardship?

The research question aims to evaluate how effective the developed framework is in helping practitioners make decisions that balance economic value and environmental stewardship. This entails analysing how well the framework addresses the trade-offs between economic and environmental factors, enabling businesses to navigate the complexities of business ecosystems.

1.6 Research Design

The research is conducted in accordance with the design science research methodology, which entails an iterative process of designing and studying artifacts developed by Wieringa[74].

1.6.1 Design Science Research Methodology

This research will emphasise three key phases of design science research methodology namely: problem investigation, treatment design, and treatment validation [74].

1. The first phase of this thesis, Problem Investigation, involves a comprehensive study of real-world problems as a precursor to designing an effective solution, as outlined by Wieringa[74]. The first chapter delves into a critical phenomenon where the prioritisation of economic factors significantly overshadows the assessment of environmental impacts, leading to an imbalance between economic and environmental considerations. For a comprehensive understanding of this issue and to determine the necessary requirements for addressing it, SQ1 is defined, and a detailed literature review is conducted to provide answers. This review gathers extensive information about the current state of both economic and environmental evaluation, providing a foundation for understanding the context in which these assessments occur. The findings from this investigation will inform the requirements for designing a treatment that promotes a more equitable consideration of both economic and environmental impacts.

2. During the second phase, known as the treatment design phase, the focus is on the interaction between the artefact and the problem context[74]. SQ2 is designed to

tackle this stage. It entails creating a solution that involves designing the artifact - in this instance, developing and refining a business value modelling framework to assess the economic value and environmental impact of the business. This artifact is then situated within the context of current practices by demonstrating it using a case study where there is a need to integrate environmental impact assessments and economic assessments.

3. During the third phase, treatment validation will be carried out to measure the utility of the proposed artifact. This validation process will involve an evaluation by experts. They will assess the proposed artifact that is applied to a specific case study to demonstrate its practicality.

1.6.2 Literature Review

An exploratory literature review on the concept of environmental impact assessment, business network modelling, and combined methods is conducted to answer SQ1. This review will be guided by the works of Webster and Watson [72] and will provide an analysis of the available literature on the aforementioned topics. The primary objective of this review is to explore, understand, and synthesise the existing studies to provide valuable insights that can be used to develop new approaches for quantifying environmental sustainability impacts and the economic value of the business network ecosystem.
This process involves a thorough examination of existing literature to establish the context and scope of the research. The broader key terms and concepts, such as e3value and Life Cycle Assessment(LCA), are identified and independently studied to build a solid foundation and gain a comprehensive understanding of the subject matter. With this understanding in place, attention turns to refining more specific terms, which are then investigated in-depth to determine the current approach and answer the research questions. A comprehensive explanation of the literature review part is described separately in the research topic and will be presented in the Appendix. The result of the literature review will be delivered in the following chapter.

1.7 Thesis Structure

The structure of this research is guided by the phases of the design science methodology which are organised as follows:

- **Chapter 1** introduces the background and motivation for the study, outlining the key issues and objectives that drive the research.
- **Chapter 2** presents the theoretical framework, discussing essential concepts such as business network models, environmental assessment, and existing methods that integrate economic and environmental evaluations.
- **Chapter 3** investigates the problem by analysing the strengths and limitations of current methods. This chapter also includes a gap analysis and identifies the stakeholders involved, along with their specific goals.
- **Chapter 4** describes the development process of the new integrated method. This chapter includes experiments with the e3value and LCA models, followed by iterative evaluations to refine the method. A case study is provided to demonstrate its application.

- **Chapter 5** details the validation process, including expert assessments to evaluate the effectiveness of the new method.
- **Chapter 6** offers a reflection on the research questions, addresses the study's limitations, and suggests areas for future work.

2 THEORETICAL BACKGROUND

In this chapter, a review of key concepts related to environmental impact assessment and business network models will be provided. Additionally, an integrated method for evaluating both environmental and economic aspects will also be covered to demonstrate. This chapter provides the broad conceptual framework and theoretical foundation of the research.

2.1 Environmental Impact Analysis

The analytical process of assessing the environmental impact of a proposed project involves a thorough examination of all potential consequences on the natural environment, as well as human health and social well-being. This evaluation takes into account both the positive and negative effects of the project. Current research is focused on exploring various methodologies and tools that can be utilised to assess environmental impact.

2.1.1 Ecological Economic Evaluation Method (EEEM)

Through the process of conducting a meticulous literature study, the term Ecological Economic Evaluation Method(EEEM) has come to the fore. This approach represents an innovative and integrated perspective that synthesises ecological and economic analyses in order to holistically assess the sustainability of policies, projects, or products. By quantifying ecosystem services and incorporating them into economic evaluations, EEEM offers a comprehensive understanding of the long-term impact of these entities.
Ma et al. conducted a thorough investigation that critically analyses different eco-economic valuation techniques employed in the steel industry. While the study mainly concentrates on the steel industry, it provides helpful perspectives into various instruments that can be applied for environmental evaluation. The study offers several conventional methods and variations of integrating all current methods[43], which is presented in table 2.1.

2.1.2 Application of Life Cycle Assessment

LCA is a highly valuable method for quantifying environmental impact. Countless studies have demonstrated the efficacy of LCA in calculating environmental impacts in various fields of study. For instance, a study conducted by Paraskevopoulou et al. employed LCA to gauge the impact of circular economy initiatives on the fruit supply chain [50], and Arzumanidis et al. used it to measure the impact of honey pollination[7]. LCA is also commonly utilised to evaluate the environmental impact of product recovery strategies. In such cases, a product life-cycle assessment approach is taken to analyse changes in environmental impacts following the implementation of product recovery management[71], as presented in the study by Wang et al.

Method

The method of LCA assesses the environmental impact of a product throughout its entire life cycle, from its creation to disposal[71]. Every study that utilised LCA adhered to the fundamental principles of the LCA framework as prescribed by the International Organisation for Standardisation (ISO) 14040:2006[1] depicted in figure 2.1.

1. Goal and Scope Definition
   The first step of conducting LCA involves defining and describing the product, process, or service being studied and setting its context[1]. During this stage, the LCA's goal is established, including who will receive the results and defining the functional unit. Moreover, the scope is defined by mapping the entire production life cycle and determining the system boundary. An example of mapping the life cycle stages using a flowchart is the production of honey, which starts from collection, processing, packaging, distribution, and waste treatment[71]. Paraskevopoulou et al. define the food supply chain into four primary categories: farming, manufacturing, marketing, and distribution. Each stage involves inputs, processes, and outputs. For instance, during the farming stage, the inputs include water, fertiliser, and fuel[50]. The processes involve activities such as harvesting and transportation to the factory. Finally, the outputs of this stage are emissions released into the water, air, and soil[50].

2. Inventory Analysis
   During the inventory analysis phase of LCA, the inputs and outputs of a product are compiled and quantified throughout its life cycle[1]. Quantifying the input and output of a product requires data. in several studies, data can be gathered manually because there may be specific data in a production and can be acquired through common databases that are widely used for inventory analysis, such as Ecoinvent, widely considered the largest, most consistent, and most transparent database which contains Life Cycle Inventory data on energy systems, transport systems, waste treatment systems, chemicals, and etc.

3. Impact Assessment
   The impact assessment is a process that evaluates the potential ecological and human consequences of energy, water, and material usage, as well as the environmental releases that have been identified in the inventory analysis[1]. In the process of the impact assessment, the practitioner should select impact categories for analysis and categorise the environmental impacts into various types, such as global warming potential, ozone depletion, and other ecosystem impacts. Then, link each environmental input or output, such as emissions, to these effects. In simpler terms, this process converts inventory data into a set of potential impacts. There are two methods that are commonly used in the literature for this purpose: the CML method and the ReCiPe Midpoint (H) method.

4. Interpretation
   During this phase of the LCA, it is necessary to assess the outcomes of the inventory analysis and impact assessment that were carried out so as to be able to choose the most suitable product, process, or service, taking into account any uncertainties and assumptions that were made during the analysis[1].

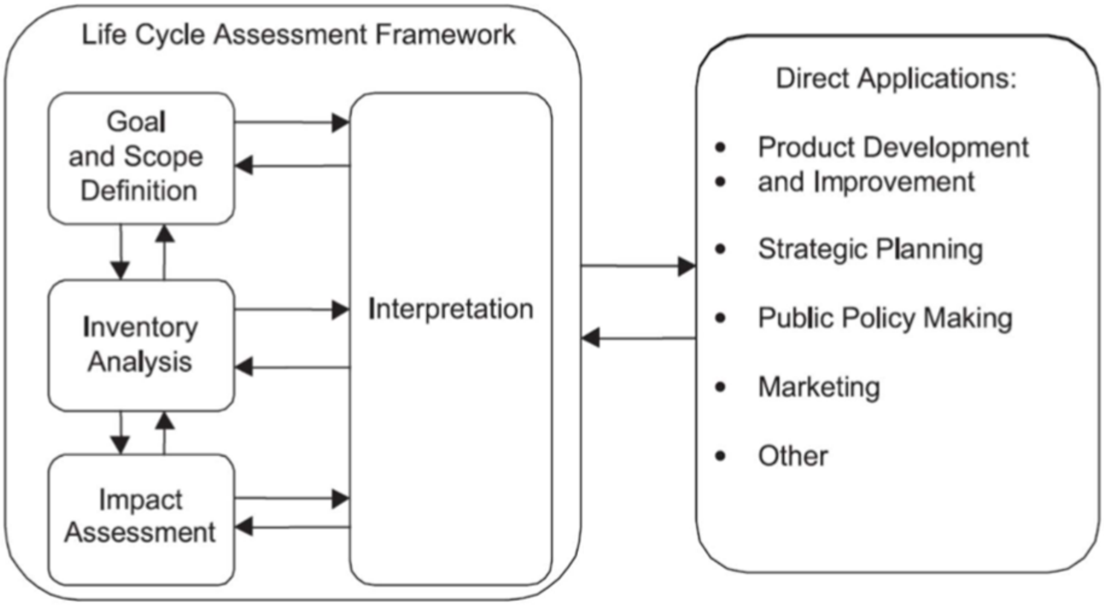


Figure 2.1: Life Cycle Assessment [1]

Tools

In the realm of LCA, which is the systematic analysis of the environmental impact of products throughout their entire life cycle, several tools have been developed to facilitate this complex process. Among these tools, SimaPro and OpenLCA are noteworthy for their comprehensive capabilities in conducting LCA. To perform an accurate assessment, LCA software is usually embedded with reference data for inventory analysis, such as eco-invent. However, practitioners can also incorporate primary data sourced from internal data in order to ensure the assessment is as precise as possible. Additionally, LCA software typically includes several databases to perform impact analysis, such as Recipe, TRACI, and IMPACT, among others. These capabilities are essential for accurately evaluating the potential environmental impacts associated with a product's lifecycle from raw material extraction through to disposal.

2.1.3 Combination of LCA and Other Evaluation Method

In a comprehensive literature review, LCA may be utilised in conjunction with other assessment methodologies. Lundgren et al. specifically delve into the realm of the built environment, analysing the cyclical impact of a circular business model within this industry[42]. Furthermore, the study integrates the assessment of economic implications through the use of Life-cycle profit[42].
Another study by Cantero-Durango et al. specifies the use of LCA with Life Cycle Cost Analysis(LCCA)[13]. The study evaluated two sustainability aspects - the environmental impact and the production cost. To estimate the environmental burdens and monetary costs associated with asphalt concrete production, the research utilised the LCA and Life Cycle Cost Analysis (LCCA) methodologies[13].

EEEM	Description
Substance / Material Flow Analysis (SFA/MFA)	The evaluation of the movement and storage of materials within a specified production, economic or social system is conducted in a structured manner. This involves utilising techniques such as mass conservation, analysis of the system, index analysis, and models for predicting material flow. SFA/MFA can evaluate the loss and benefits of specific substances in a specific area and the impact of various processes on the environment.
Economic Value Assessment (EVA)	Economists have suggested various methods to assign market values to environmental economic systems such as observed preferences, revealed preferences, stated preferences, budget constraints, and abatement costs.
Life Cycle Assessment (LCA)	The method of life cycle assessment (LCA) involves assessing the input, output, and environmental impact of a production system throughout its life cycle. This includes evaluating the preparation of the system and its potential environmental effects.
Energy/Emergy Analysis (EnA/EmA)	EnA, which stands for Energy Analysis, refers to the examination of the energy flow, transformation, and storage processes within a system utilising energy as a standard unit of measure.
Footprint Analysis	Different types of footprints have been proposed since the introduction of the ecological footprint in the 1990s. The family of footprints includes the ecological footprint, energy footprint, and water footprint.
Ecosystem service evaluation (ESV)	A framework for identifying, quantifying and assessing Ecosystem Services. There are four main categories of Ecosystem Services: provisioning, regulating, cultural and supporting services.

Table 2.1: Eco-economics Assessment Method[43]

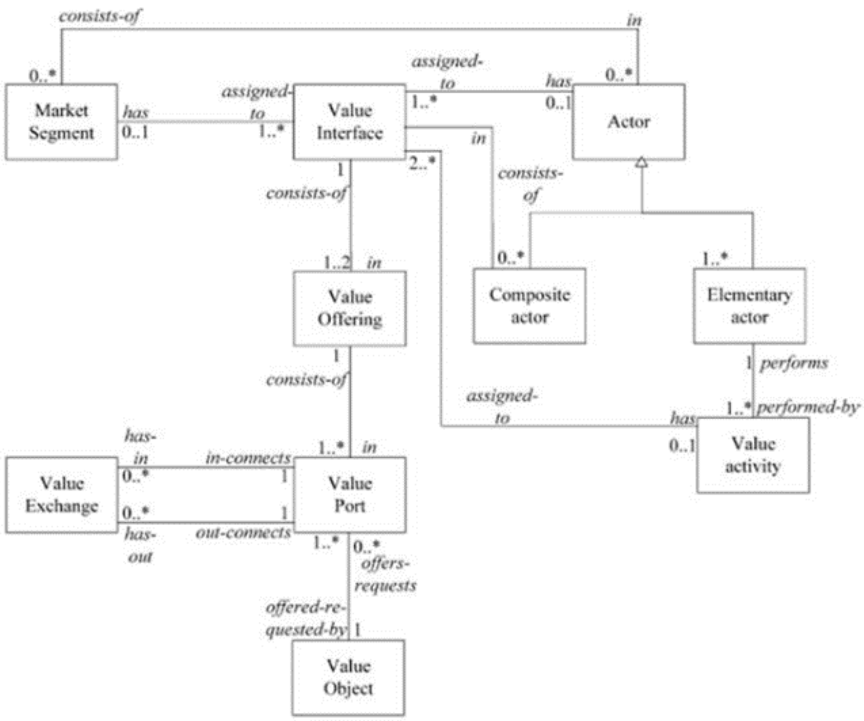


Figure 2.2: E3value Ontology[30]

2.2 Business Network Model

As part of the literature review, various business network models have been identified, including e3value, Dynamic Value Description (DVD), Systemic Enterprise Architecture Method (SEAM), and Resource Event Agent (REA). Below is a short overview of each of these method :

- E3value

  Value modelling is a widely used approach to business modelling that focuses on the exchange of value objects within business networks. The e3value methodology, developed by Gordijn, integrates IT systems analysis with a business-focused economic value perspective[30]. e3value is a part of business modelling that focuses on the interaction of actors and their value flows. Its primary purpose is to establish the development and exchange of economic value among a group of participating actors, with a specific emphasis on achieving mutual value exchange. In the given diagram, labelled as Figure 2.2, we can see the ontology of e3value. This ontology illustrates the various components of e3value and their interrelationships. It defines how these components can be utilised correctly. The rectangular shapes in the diagram represent the various components such as market segment, value interface, actor, etc. An example of the relationship depicted in the diagram is between the market segment and the actor. One market segment may consist of a minimum of zero actors and can have many actors. Conversely, an actor can belong to zero or many market segments. To provide a better understanding of e3value, an example of its usage is depicted in Figure 2.6 and 2.8.

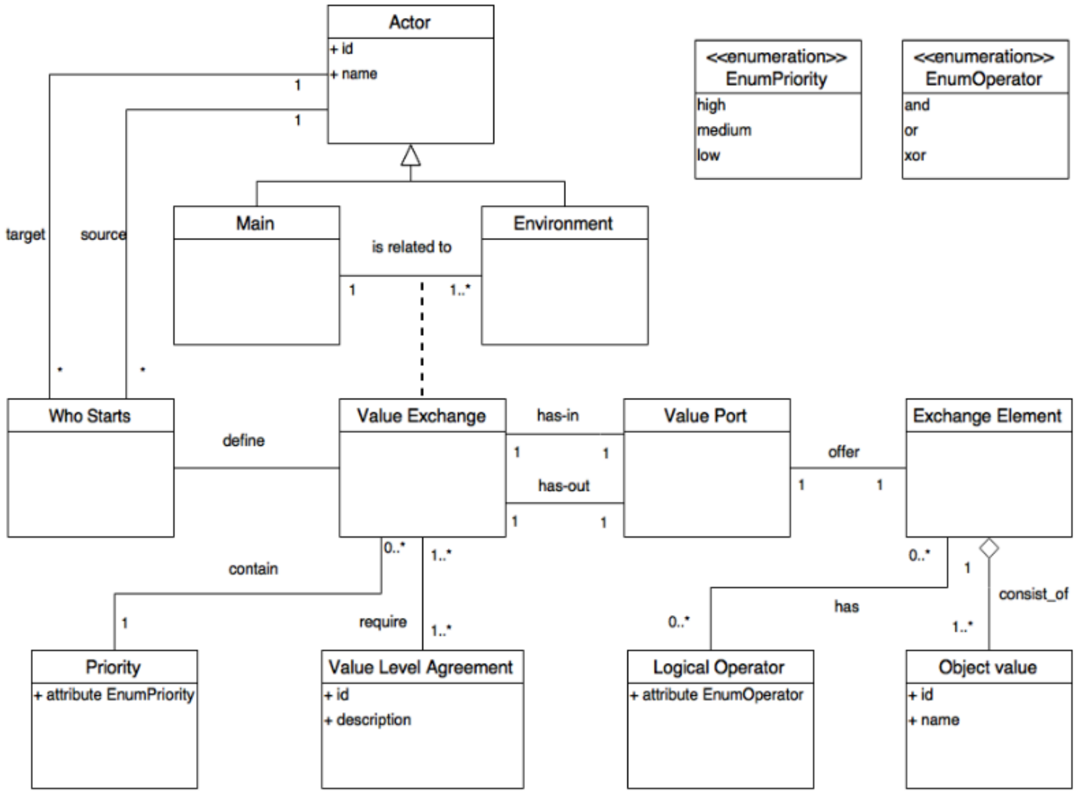
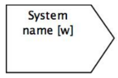
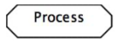


Figure 2.3: DVD Metamodel[65]

- DVD (Dynamic Value Description)
  DVD is a crucial component utilised in the Value-driven development methodology. This approach aims to establish software architecture that is in harmony with the economic values of a business, aided by model-driven techniques[65]. DVD plays a pivotal role in analysing and representing the exchange of economic values during the early requirements phase[65]. Figure 2.3 illustrates the metamodel of a DVD, which comprises a rectangle representing the DVD component and lines with arrows that display their respective relationships. The metamodel contains two actors, namely the main actor and the environment actor, both of which possess generalisation as an actor. According to this metamodel, each main actor should be linked to a single value exchange, whereas the environment actor can be linked to one or more value exchanges. Figure 2.7 depicts the example of the DVD model and more explanation about the model will be given in the next sub-chapter.

- SEAM (Systemic Enterprise Architecture Method)
  SEAM represents the seamless integration of business and IT, encompassing the SEAM philosophy, method, and computer-aided design prototypes[73]. It can be difficult to come across the SEAM ontology, but the legend represented in figure 2.9 clearly outlines the basic components that make up the SEAM. These components include Business, Human, Information System, Service, Process, Exchange Relation, and Refinement Relation. This emphasises the way in which businesses offer services within a value network, as explained in [41]. The legend of SEAM is aligned with the SEAM modeling language visual vocabulary defined by [69], which consists of

Table 2.2: SEAM Visual Language Description[69]

Category	Component	Visualisation	Description
System	System		An entity in the perceived reality, such as a company, a department, or an organisation. A system has two views, whole and composite. A small letter in square brackets, [w] or [c], is added as a suffix to the system name to denote which view is shown.
System Behaviour	Service		The behaviour of a system as a whole representing a service offered by a system.
System Behaviour	Process		the behaviour of a system as a composite defining a service implementation.
Links	Invoke		Use (invoke) link between services and processes in a system as a composite. This link means that the process uses (invokes) the connected services.
Links	Refinement		Refinement (decomposition) link, connecting the abstract and concrete view of a system, [w] and [c] respectively. The services from the system as a whole have corresponding processes in the system as a composite. These processes show the implementation of services.

system, system behaviour and link. Table 2.2 provides more explanation for each component. The SEAM model for Intellectual Property Rights(IPR) depicted in Figure 2.9 sheds light on the IPR society's role in enabling public music playback[41] which will be explained more in the following sub-chapter.

- REA (Resource Event Agent)
  The REA principles are rooted in traditional accounting practices, but instead of relying on double-entry bookkeeping, it employs semantic models to represent economic transactions and conversions [60]. The REA ontology asserts that any multiparty collaboration can be broken down into a series of corresponding binary collaborations, provided there is an exchange of money and a market for prices [60]. Designed to model values in business processes, [35] present the detailed ontology of REA. However, the basic concept of REA is based on UML class diagrams provided by [60] depicted in Figure 2.4. The figure showed that REA has three main components, which are economic resources, economic events, and economic agents. The REA example showcased in Figure 2.5 depicts a straightforward collaboration between a buyer and seller. The exchange of economic resources in this scenario involves money and goods, with payment being the economic event triggered by the exchange of money, and shipment being the economic event triggered by the

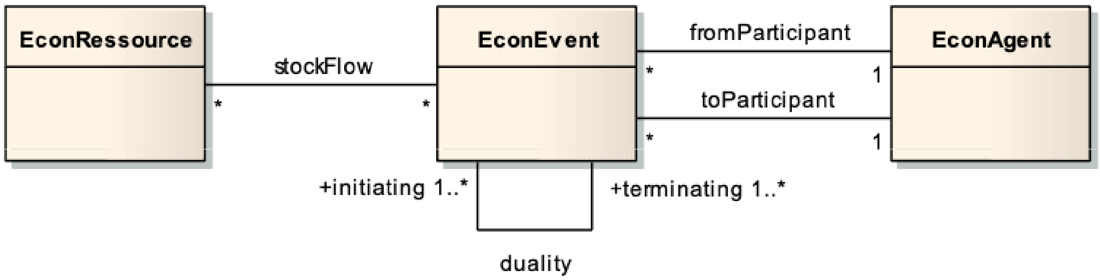


Figure 2.4: REA Basic Concept[60]

exchange of goods.

2.2.1 Comparison of Several Business Network Models

Souza et al. conducted a study that compared two business value modelling methods: e3value and DVD. The study offered practical evidence of the effectiveness of both techniques and their potential for acceptance in practice[66]. The objective of the study was to evaluate the relative efficacy of DVD and e3value with the aid of three perception-based variables: Perceived Ease of Use, Perceived Usefulness, and Intention to Use. The researchers conducted an experiment wherein both methods were introduced to participants who had no prior experience with either modelling tool. Based on the results, DVD was found to be more effective than e3value.
The outcome of the comparison of the aforementioned study is not directly related to the goal of this research. However, it provided insights into the similarities and differences between e3value and DVD. While both methods share the same objective and fundamental concepts, they differ significantly in notations, structure, and construction processes. The study also presented a conceptual comparison between DVD and e3value, indicating that the e3value model comprises more concepts, while the DVD model aggregates some of the ideas from e3value and introduces a new attribute, the value level agreement, which specifies the qualities for each value exchange[66]. The Conceptual comparison between both models is presented in Table 2.3
Souza et al. also offer insightful illustrations of the e3value and DVD models, both of which depict a scenario where a store sells products obtained from a wholesaler to customers. These examples are useful in clarifying the mechanics of the models. In Figure 2.6, the e3value model shows that the Shopper is classified as a market segment, while the Store and Wholesaler act as actors. All actors and market segments engage in the exchange of goods and money as part of the value exchange process. Each actor and market segment can undertake value activities that generate value. For instance, the Shopper's activity is buying, the store's activity is retailing, and the wholesaler's activity is selling. All activities provide value ports and value interfaces, which enable all stakeholders to exchange value. Figure 2.7 illustrates a scenario similar to the one mentioned earlier. The Store is the key actor in this case, representing the model's perspective, while the shoppers and wholesalers are environmental actors. The value exchange is depicted within the environment, with money and goods exchanged between the store and the shopper. Notably, the value exchange flows sequentially from the shopper to the store and finally to the wholesaler. The relationship between these actors is more about the flow of value exchange. In DVD, we can incorporate quality agreements as a requisite for value exchange to occur.

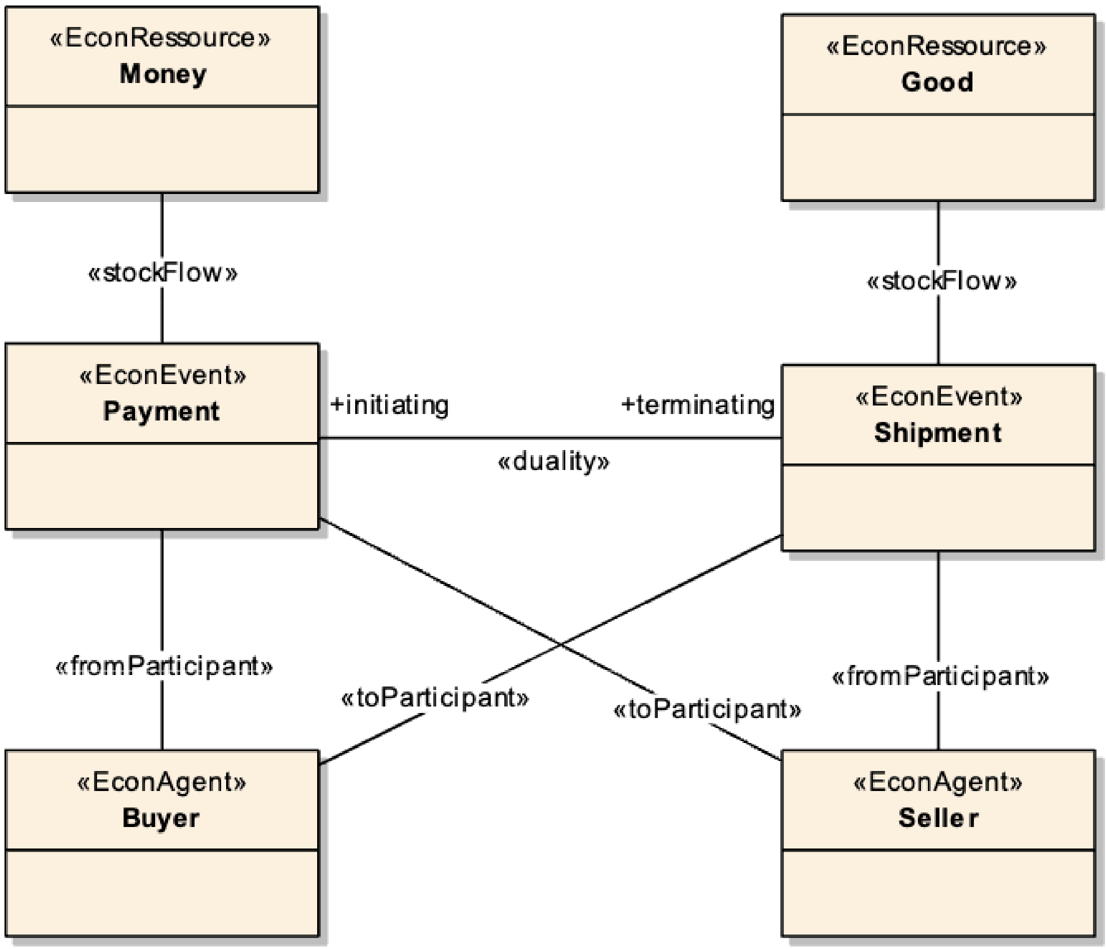


Figure 2.5: Example of REA[60]

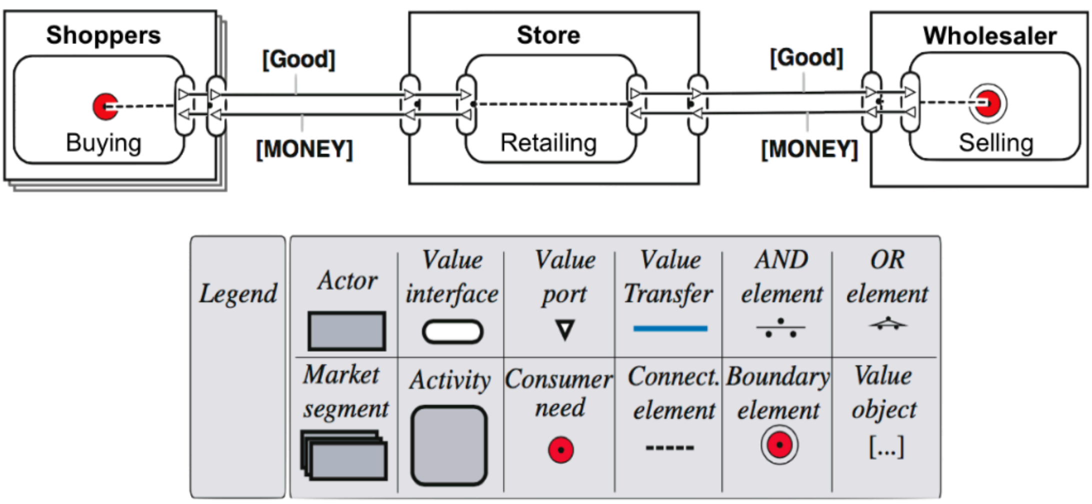


Figure 2.6: Example of E3value - 1[66]

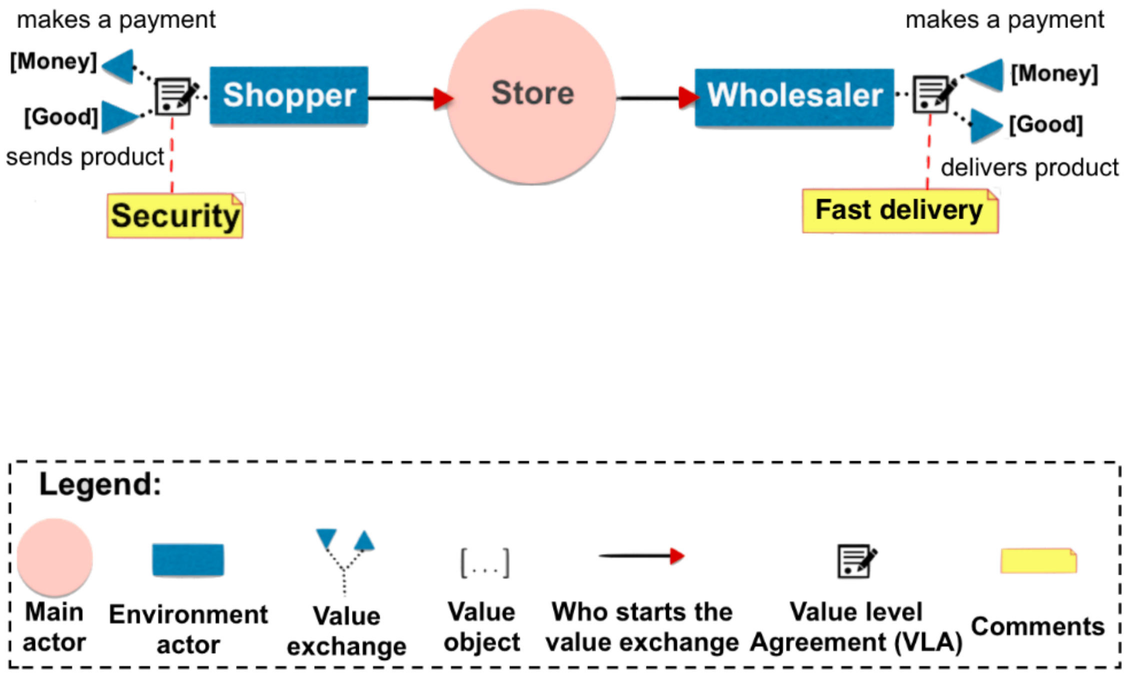


Figure 2.7: Example of DVD[66]

Table 2.3: Comparison of E3value and DVD Concept[66]

e3value	**DVD**
Elementary actor	Main actor or environment actor
Composite actor	Main actor or environment actor
Market segment	Main actor or environment actor
Value interface	Aggregated in value exchange
Value transfer	Aggregated in value exchange
Value port	Value port
Value object	Value object
Value exchange	Value exchange
Value transition	Aggregated in value exchange
Value activity	-
UCM Start stimulus	Who starts
UCM Stop stimulus	Who starts
UCM AND element	Logical operator in value element
UCM OR element	Logical operator in value element
UCM Connect element	-
-	Value level agreement

Table 2.4: E3value and SEAM Comparison[41]

Dimension	**Feature**	**SEAM**	**e3value**
User	Need Coaching	Yes	Yes
	Adressee	Modeller	Modeller
Purpose	Context Analysis	Yes	Yes
	Stakeholder's alignment	Yes	Yes
	Type of Analysis	Socio-technical networks analysis	Economic Viability
Language	Graphical	Yes	Yes
	Formally Specified	Yes	Yes
	Possible Analysis	Qualitative	Qualitative & Quantitative
	Concept	Service-oriented	Economic
Mapping	Heuristic for modelling	Yes	Yes
	many models	Yes	Yes
	model transformations	Motivational analysis, IS applications	BPM, motivational analysis
Origins	SE/RE method	Yes	Yes
	Foundation	Service Science	Business and economics
Application	Primary domain	Research and teaching	Research and teaching
	Practitioners community		
	Tools	Yes	Yes
	Well-known in academia	-	Yes
	Evaluation of use		Yes

Kostova et al. undertook a study to compare the e3value model with SEAM, with the aim of aiding modellers in selecting an appropriate model based on their requirements. A particular comparison framework was utilised to analyse the distinctions and parallels between e3value and SEAM via a case study experiment. The resemblance between e3value and SEAM has been emphasised in the paper. The result showed that there is a considerable intersection between e3value and SEAM[41]. Table 2.4 showed the result of the comparison of both models.

The study compared both models using qualitative analysis based on several attributes (Users, Purpose, Language, Mapping, Origins, and Application)[41]. Both models concentrate on services in networked systems and give importance to the exchange of value. The result shows that e3value is a method that maps economic transactions between parties, with a focus on quantifying money exchange, whereas SEAM takes a more holistic and flexible approach by not only considering money but also other kinds of value that may be exchanged, such as services or benefits that are difficult to measure[41].

The author of [41] offers an insightful example comparing SEAM and e3value, featuring the Intellectual Property Right (IPR) case study. The detailed case was originally presented by Hotie and Gordijn to showcase a service tailored for IPR business[34]; this case study serves as a useful reference point for the comparison. To give more context, the simplified

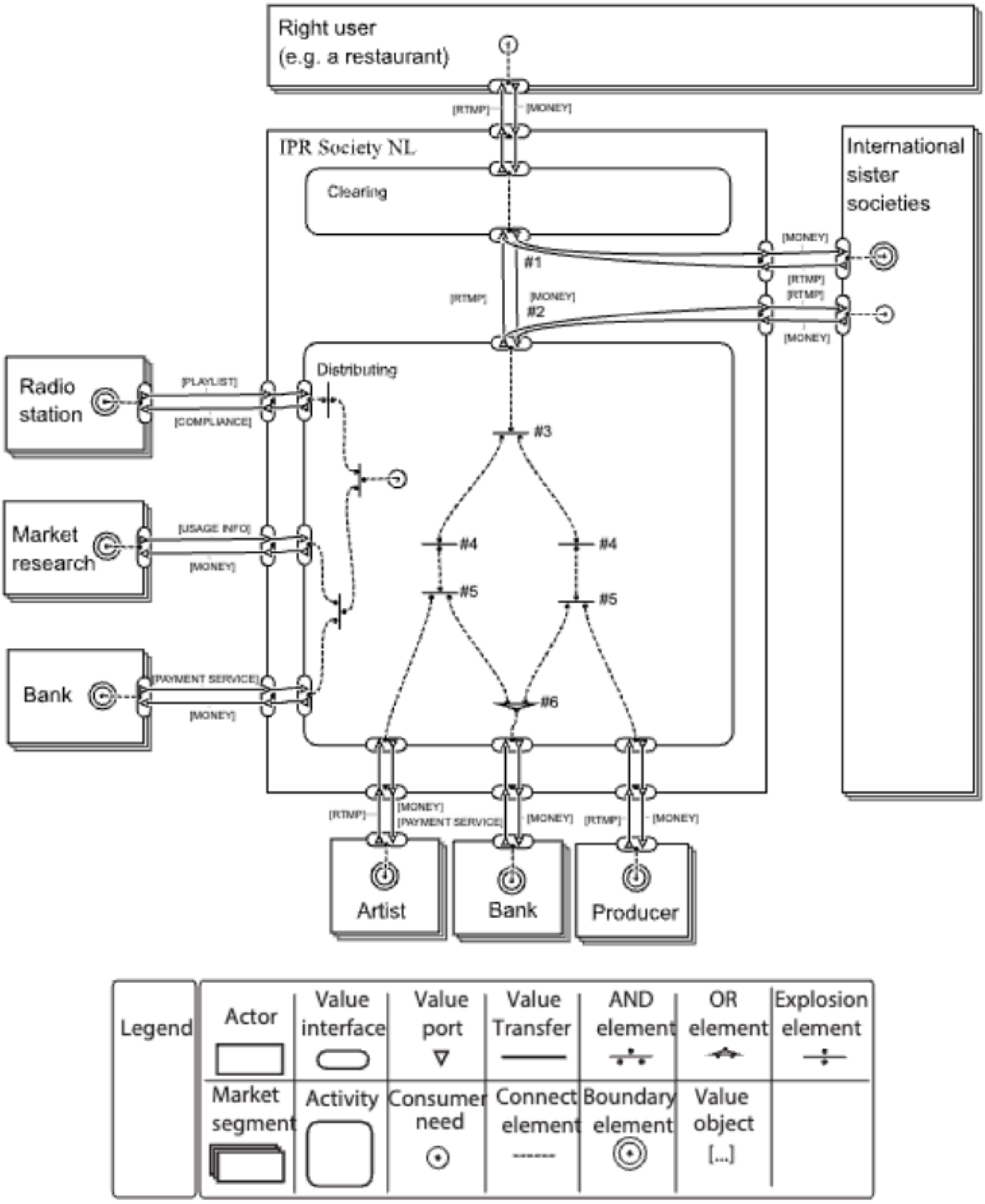


Figure 2.8: Example of E3value - 2[41]

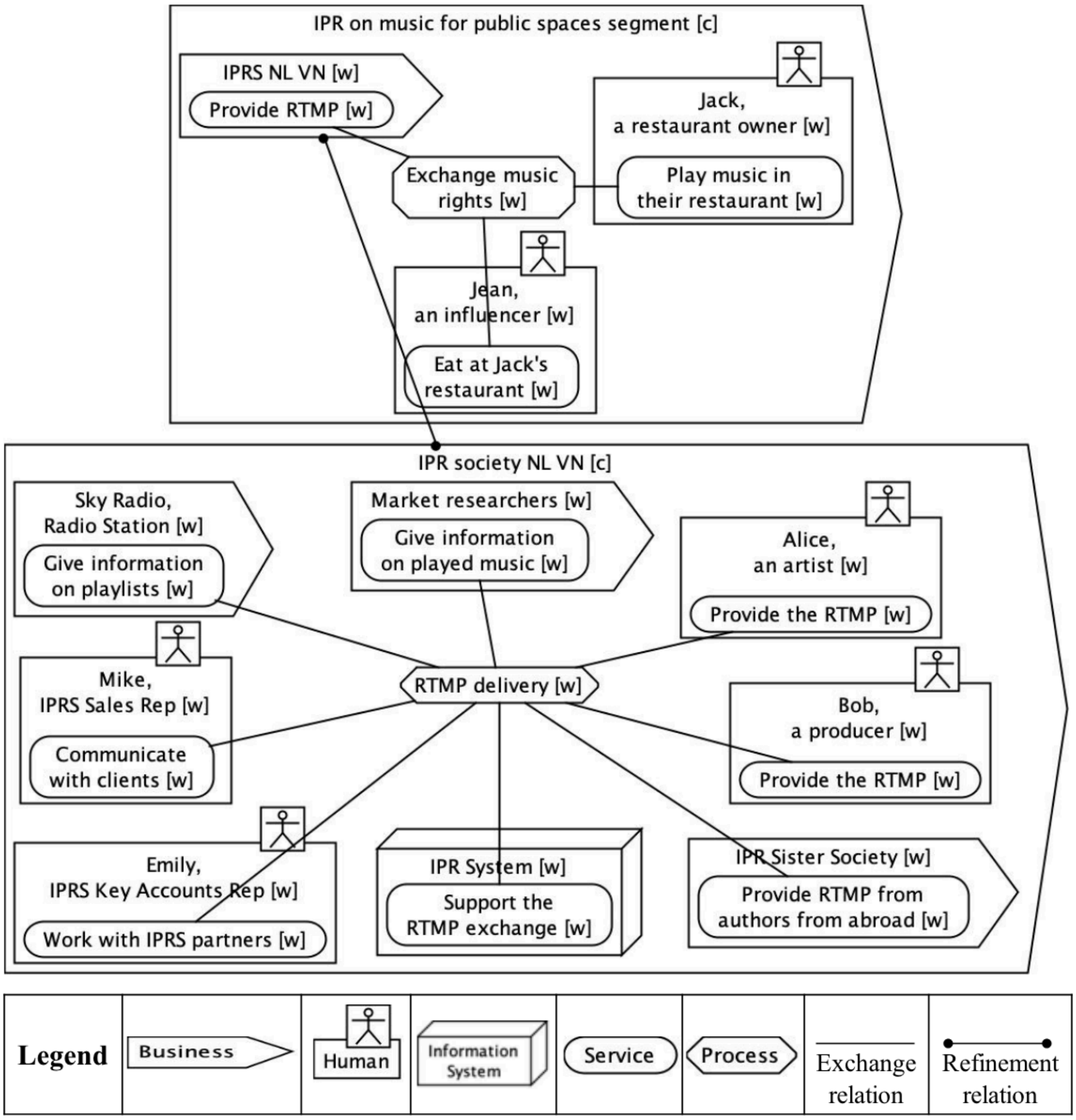


Figure 2.9: Example of SEAM[41]

version from the [41] of the case will be presented below.
Public broadcasting of music involves four key players: the entity that plays the music (rights user), the music's owner (rights owner), and two intermediaries known as Intellectual Property Rights (IPR) societies. These societies collect fees from entities like cafes or radio stations and distribute these to the music owners. When music is played internationally, IPR societies from both the country of the rights user and the country of the rights owner collaborate to manage the fee transactions, similar to how banks handle international fund transfers. Fees are generally a fixed annual amount determined by the venue's size and the music's significance to the broadcaster. IPR societies maintain a database of music and its ownership and require major broadcasters to submit playlists. They also conduct market research in various venues to track which songs are played and compile this data to ensure fair payment distribution among rights owners. This payment allocation process is called repartitioning.
The e3value model showcased in Figure 2.8 within the IPR case study features IPR society as a key actor, with market research, banks, artists, producers, international sister societies, right users, and radio stations designated as market segments. In this model, the focus of value activity is on IPR society, while the value activity for the market segment is not specified as it is not applicable in this context. The market segment serves to provide an understanding of the value exchange among all stakeholders associated with IPR society.
In contrast, the model illustrated in Figure 2.9, known as the SEAM model, presents a unique approach to the same scenario. It depicts two distinct systems: the smaller box represents how the IPR Society interacts with external systems, while the larger box demonstrates how the IPR delivers within its own system. Each system box has different actors and businesses operating inside it. Unlike other models, the SEAM model places emphasis on the actors' behaviour both inside and outside the system and their role in the delivery process rather than solely focusing on the value exchange.

2.2.2 Adoption of E3value

The e3value modelling provides a concise and efficient approach to depict the value exchange that takes place within a business network. It offers a clear understanding of the value proposition of each entity involved in the network and how it benefits from the exchange. The literature study found that e3value is a commonly used concept that has been widely adopted.
The e3value model can be used to determine the feasibility of new business cases, as demonstrated in[36]. This paper shows the application of e3value to assess the impact of dynamic pricing in the electricity market. It also highlights the advantages and drawbacks of using e3value in the context of the energy market. From this research, it can be concluded that the e3value methodology presents a valuable method for analysing and communicating the complexities of the liberalised energy market, offering significant advantages in terms of visual accessibility, economic analysis, and model adaptability[36]. However, its application requires careful consideration of the trade-offs involved, particularly the need to balance the benefits of simplification against the potential loss of detail and accuracy in capturing market dynamics[36].
E3value model can also enhance the business case of inter-organisation projects. A study by Eckartz et al. represents the use of value modelling to help clarify cost and benefit analysis in value networks. It has been stated that incorporating a value model is an essential enhancement in the development of business cases within inter-organisational contexts[21]. By including a value model in a business case, it elevates the standard

of the business case by explicitly presenting the available options that are relevant to the network's stakeholders, which results in a better understanding of the options for all parties involved[21].
A recent study by Bon et al. used e3value to model the sustainability of business services for digital inclusion. The study focused on applying e3value to several study cases to determine if this method is practical and useful for practitioners and if this method is effective in developing sustainable services for digital inclusion[10]. The results indicate that the e3value method is user-friendly and practical for various applications. It effectively aids in the visual conceptualisation of business scenarios, enabling discussions and collaborative construction, and is useful for evaluating potential profitability within the value web. Additionally, it assists in optimising system design and analysing the value network's strengths and weaknesses, particularly regarding digital inclusion[10].

2.2.3 Expanded Use of E3value

In the previous subchapter, there were several examples of e3value's practical application as a modelling method. The examples demonstrated how e3value can effectively model interactions and value exchanges between entities in an ecosystem and measure their economic value. This chapter will explore various research studies highlighting how e3value can be extended and integrated with other theories to capture the complex dynamics of business networks.
e3value is a modelling method that comes from requirement engineering studies as it aids in quantifying the exchange of value and presenting the ideal situation for a proposed business, thereby showcasing how value is exchanged among stakeholders. However, a study by Ionita et al. has highlighted that non-ideal conditions may exist in the proposed business model and extended e3value into the e3fraud model. The study has proposed methods for carrying out sensitivity analysis, fraud analysis, and sustainability analysis. The result showed that value models are not just useful for estimating the profitability of a new e-business idea; they can also be extended for quantitative risk and sensitivity analysis[38].
Valja et al. explore the integration of utility theory with e3value models[70]. This approach is proposed to enhance the understanding of how customers perceive the value of a business's offerings compared to its competitors. Their work addresses a gap in existing business model frameworks, which often overlook a detailed analysis of perceived customer value.
Johnson et al. proposed an approach that combines e3value with a predictive, probabilistic architecture modelling framework. This advanced framework enables accurate and reliable reasoning about profitability risks based on the e3value modelling language and the object constraint language[40].
A value model plays a critical role in the success of a business network ecosystem. It focuses on the economic value that is exchanged within the network. A study conducted by Hotie and Gordijn emphasizes how this value can be accomplished[34]. The study primarily focuses on deriving a process model from the value model. In other words, it explores how the value model can be transformed into a model that outlines the processes required to achieve the desired results.

2.3 Integrating Business Network Model and Environmental Impact Assessment

A research study that successfully integrates the distinct viewpoints of the business network model and environmental impact assessment is rare. While both areas are crucial in their own right, their combination remains atypical. In this regard, the research conducted by Gonzales-Salazar et al. further confirms this observation by highlighting the challenges that come with the concurrent evaluation of the economic and environmental effects of a product[28]. The study proposes a new method, the Life Cycle Assessment - Net Present Value (LCA-NPV), to determine both the economic and environmental impact of an electric vehicle's circular business model.

The study provides an in-depth analysis of the economic value of battery leasing and selling models from both the manufacturer and customer perspectives. This analysis uses Net Present Value (NPV) to quantify factors such as revenues, costs, investments, depreciation, and taxes in order to determine profitability[28]. Additionally, the study uses LCA to evaluate the environmental impact of these business models throughout the entire life cycle of leasing and selling batteries[28]. This includes all stages of the battery life cycle, from raw material extraction and manufacturing to distribution, use, and end-of-life processes. The environmental evaluation relies on data sources that provide information on the environmental impacts of battery production, usage, and disposal.

The objective of the ongoing research is to perform a comprehensive analysis of various economic and environmental factors. It is worth mentioning that this study differentiates between the business model and the quantification method to ensure an accurate evaluation of both the economic and environmental value. The key to achieving this objective is to redefine the business model and quantify all values based on the newly defined process. As the study is focused on comparing the economic and environmental value of selling and leasing a battery, two business models have been created to account for the different processes involved. The assessment yields a comprehensive economic and environmental value for all stakeholders rather than individual values for each one.

According to the study, the NPV method is valuable not only to manufacturers but also to customers. By considering both costs and revenues, as well as the time value of money, which considers the effects of present and future investments, depreciation, and taxes, NPV is a robust methodology for measuring economic and environmental value in tandem. The study, however, only examined NPV in the contexts of battery leasing and battery selling. While the method can be applied to other industries, it is essential to account for different business models. NPV calculations in other fields may not be comparable to those in the case study. As such, it is necessary to establish certain parameters before implementing NPV in other industries.

Bockin et al. conducted a study that introduces the innovative method of Business Model Life Cycle Assessment (BM-LCA) for evaluating the environmental impact of a business model[12]. Unlike the conventional LCA approach, BM-LCA concentrates on the business model itself. It is an extension of the LCA with a more comprehensive goals and scope definition aspect, which outlines the financial flow of the business model and the tangible flow of the product or service, resulting in the measurement of both economic and environmental impacts[12]. The description of BM-LCA can be found in Figure 2.10

Previous studies convey the concept of BM-LCA, while Goffetti et al. have applied BM-LCA to compare two different business models. They used BM-LCA to evaluate the environmental performance of a Swedish apparel company's sales business model against a rental business model[27]. The study suggests that BM-LCA provides a quantitative

Business Model LCA

Phase	Description of each step
Goal and Scope: Descriptive phase	Give general description of the setup of each business model to be compared and of the related product(s) and state the relevant time period.
	Define system boundaries and environmental impact categories of the assessment. Map actors in the product chain.
	Find the connection of how the amount of production, q, depends on the number of transactions, t, for each business model.
Goal and Scope: Coupling phase	Step 1: Define the functional unit as the profit, π, that each business model must achieve.
	Step 2: Identify all of the business' costs and revenues associated with running one of the business models for the stated period. Find conversion factors, f, to couple costs and revenues to customer transactions, t. Set up an equation for the profit as revenues minus costs: $\pi = f_{revenue} * t - f_{direct} * t - f_{indirect} * t - f_{contingent} * t$
	Step 3: Solve the equation to find the transactions, t, required to reach the profit. Derive the required amount of production, q.
	Step 4: Repeat steps 2 and 3 for every business model to be compared.
Life Cycle Inventory	Construct a system model and quantify all environmentally relevant flows, scaled according to the functional unit.
Life Cycle Impact Assessment	Aggregate all flows from LCI and quantify their effects on the chosen environmental impact categories.
Interpretation	Analyse the results and scrutinise their robustness to identify pros and cons of compared business models.

Figure 2.10: Summary of BM-LCA[12]

approach to assess the environmental performance of different business models and can be used to validate the sustainability claims of a business model[27].

LCA-NPV and BM-LCA are effective methodologies for measuring a product or service's economic and environmental impact. They both use Life Cycle Assessment (LCA) to evaluate the environmental impact, but there are some differences between the two. LCA-NPV provides a more comprehensive analysis by incorporating factors such as cost, revenue, and future cash flows to quantify a product or service. While LCA-NPV is a stakeholder-agnostic method, BM-LCA places greater emphasis on integrating LCA with the business model-oriented approach. However, both methods do not account for the crucial economic and environmental value exchange among all stakeholders in the business ecosystem.

3 PROBLEM INVESTIGATION

Following the design science research methodology, this chapter will explore the current landscape of environmental impact assessments and business network models to address SQ1. Then, it will assess the drawbacks of current methods to identify significant gaps and challenges. Finally, it will examine potential stakeholders and their requirements to establish a solid foundation for defining the design requirements of a new, integrated method.

3.1 State of The Art in Environmental Impact Assessment and Business Network Models

3.1.1 Environmental Impact Assessment

Table 2.1 introduces an eco-economics assessment method that can be used to assess the environmental impact of a project or activity. This method evaluates the environmental impact by measuring it in economic terms. It focuses on translating environmental impacts into economic terms and assessing the economic implications of these impacts. This helps businesses understand the financial consequences of their environmental actions. It is particularly useful for assessing costs and benefits in situations where environmental considerations must be weighed.

In contrast, LCA provides a detailed environmental analysis without necessarily translating impacts into economic terms. It is a thorough method used to evaluate the environmental effects linked to every stage of a product's life cycle, from the extraction of raw materials to disposal or recycling. LCA offers a complete perspective on environmental impacts, which makes it an important approach for comprehensive environmental analysis. LCA is a frequently employed methodology that holds significant importance in diverse fields for assessing environmental impact[59, 58].

LCA offers a comprehensive evaluation to gauge the overall environmental impact of a product or service[16]. It takes into account all activities related to the product, quantifies its environmental impact, and encompasses all interconnected activities, media, and effects. LCA acknowledges potential trade-offs among different stages of a product's life, geographical areas, and environmental concerns arising from a particular choice[16]. The strength of LCA lies in its ability to support strategic decision-making in business and promote optimised environmental performance for products. The results of LCA can be used to make more environmentally friendly purchasing decisions. By providing quantitative analysis with solid environmental data, LCA helps in understanding the production stages that have the most impact.

LCA possesses the additional advantage of promoting extensive communication and meaningful discourse[16]. It is an efficient way to communicate reliable information about the environmental performance of products.[19]. The outcome of a Life Cycle Assessment (LCA) can act as a method to transparently communicate the environmental footprint of a product, process, or service, thereby preventing green-washing practices. This empowers businesses to offer reliable data to substantiate their sustainable claims. It also promotes transparency, enabling customers to make well-informed decisions. Sharing environmental data on products enhances a company's credibility and can foster stronger customer trust and loyalty.

LCA has numerous strengths, but it also has some limitations. LCA is a standardised and comprehensive method for evaluating the environmental impact throughout the life cycle of a product or process, which makes it robust in assessing environmental footprints. Nevertheless, despite its comprehensive nature, LCA frequently encounters challenges in effectively integrating economic aspects[44]. The economic dimension, crucial for businesses seeking to reconcile sustainability with profitability, is not inherently embedded within the LCA framework.

Additionally, LCA is a resource-intensive process that requires detailed data to accurately assess the inputs, processes, and outputs of products and services. This level of detail makes LCA both time-consuming and highly dependent on the availability and quality of data. Furthermore, the dynamic nature of LCA poses challenges, as even minor changes in inputs or interactions within the LCA process can significantly alter the overall results[16]. Conducting a comprehensive LCA study also demands specialised skills, particularly in the phases of data collection, processing, and interpretation, which can further complicate its implementation.

3.1.2 Business Network Model

Chapter 3.2 explores various value modelling concepts, including DVD, SEAM, e3value, and REA. These methods provide invaluable insights into complex business models, strategies, and systems through graphical representations. These visualisations aid in the clear and concise analysis and communication of intricate ideas, enabling businesses to make informed decisions and improve outcomes. Each modelling method offers a unique perspective and ontology for dissecting and representing the intricate relationships and transactions within a business network. The graphical representations are integral to their analytical capabilities.

All the methods that are explained have the capability to do a qualitative assessment of the economy. E3value, in particular, is noted for its promising approach due to its ability to quantify economic value and extend to areas such as fraud detection and utility analysis. This versatility makes it a valuable method for evaluating different aspects of business models, offering insights that can lead to strategic improvements and enhanced operational efficiency.

E3value was originally created as a means to model and examine the generation and dissemination of economic value within networked business models, specifically in the realm of electronic commerce[30]. E3value presents a transparent and organised method for illustrating how value is generated and traded among various participants within a network. It enables businesses to conduct scenario-based analyses[30], giving them the ability to investigate different setups of value networks and evaluate their economic potential.

The e3value model is widely recognised for its ease of use, making it an accessible method for business users to model economic value exchanges within a network. Its straightforward, graphical representation allows users to quickly understand and map out the value flows between different actors in a business ecosystem[30]. However, while its simplicity and high level of abstraction contribute to its user-friendliness, these same characteristics can also be limiting. The model primarily focuses on economic exchanges, which means it may overlook other critical aspects of business models, such as social or environmental value creation, regulatory constraints, or organisational dynamics. Moreover, by operating at a high level of abstraction, e3value might oversimplify certain aspects of business operations and fail to capture the detailed processes that can significantly impact value creation. Thus, while e3value is an effective and easy-to-learn method for economic modelling, users should be aware of its limitations when applying it to more complex, multifaceted business scenarios.

3.1.3 Combined Methodologies

During the literature review, two methods for assessing the economic and environmental impact of a product or process were identified: BM-LCA and LCA-NPV. BM-LCA is a modified LCA method that incorporates a business model perspective. Its key innovation lies in linking economic performance to the product system, thereby connecting LCA to business advantages[12]. The process involves comparing business models by mapping product chain actors, defining a profit-based unit, and setting up economic equations. In BM-LCA, the goal and scope definition step is expanded to include business models and economic considerations. Standard LCA methods are then used to assess environmental impacts.

The LCA-NPV method expands traditional LCA by integrating the quantification of NPV for economic assessment. While effective in capturing the economic value of environmental impacts, this approach is constrained by its emphasis on NPV as the primary metric. In diverse business scenarios, particularly when evaluating a network of businesses, the economic metrics for evaluation can significantly vary among the involved parties. The reliance on NPV limits the method's flexibility to fully accommodate the diverse economic considerations crucial in a complex business network.

3.2 Gap Analysis and Stakeholder Needs

3.2.1 Gap Analysis

Business models are often viewed through a value creation lens, focusing primarily on satisfying customer needs, achieving economic returns, and ensuring compliance[68]. However, this traditional approach is limited in scope and underscores the need for a more comprehensive framework that incorporates environmental objectives to balance, or ideally align, the interests of all stakeholders, fostering sustainable business practices[8]. To achieve sustainable business model innovation and identify opportunities for sustainable growth, an integrated method that assesses both economic and environmental aspects is essential. In the context of business model networks, which involve numerous stakeholders with diverse needs and perspectives, there is an urgent need for a methodology that can simultaneously represent the entire business ecosystem. This method must delineate value flows for both economic and environmental impacts, offer flexibility in calculating various financial metrics tailored to each stakeholder's requirements, and illustrate the trade-offs between economic value and environmental impact. Such a comprehensive overview would support more informed and effective decision-making.

LCA is a well-established method for evaluating the environmental impact of products and services throughout their entire life cycle. However, it does not fully account for the economic value exchanges among stakeholders, revealing a critical gap in integrating environmental impact analysis with business value modelling. Conversely, business network models such as e3value excel at analysing economic value but lack the necessary ontology to measure environmental impacts. This limitation hinders the development of comprehensive methods that incorporate sustainability measures and analysis of the complex interactions within business ecosystems.

While some combined methods exist, they often fall short of providing a deep understanding of the complex relationships between different entities within a business ecosystem and how they exchange both economic and environmental value. Additionally, these methods typically overlook the diverse stakeholders involved, despite the fact that business model networks consist of multiple parties with varying interests. Furthermore, current methodologies primarily rely on LCA, which, although robust in its analytical capabilities, lacks a visual representation, making it less effective in communicating value exchanges.

The literature highlights the significant advantages of integrating both e3value and LCA for a comprehensive assessment of economic and environmental factors. The decision to adopt e3value stems from its robustness, which facilitates the visual representation of all stakeholders within a business network. Furthermore, e3value offers an ontology that effectively maps value exchanges and economic interactions, with particular strength in understanding the interactions and interdependencies among diverse stakeholders within a business ecosystem. This capability is crucial for developing business network models that address the needs and expectations of all involved parties, aligning seamlessly with the research goal of conducting a thorough evaluation of the economic dimension.

On the other hand, LCA is widely recognised as a standardised methodology for environmental assessment. It provides detailed insights into the environmental impacts at each stage of a product's life cycle. LCA is particularly effective at identifying environmental hotspots where significant impacts occur, offering transparent and reliable results that complement the environmental aspects of business analysis.

As sustainability takes on a more pivotal role in shaping business objectives, the integration of e3value and LCA emerges as a strategic and compelling approach. e3value, with its robust capability to model and visualise economic value exchanges within complex business networks, addresses the need for clear, multiple stakeholder-focused economic analysis. Meanwhile, LCA provides a meticulous and thorough examination of environmental impacts across the entire life cycle of products and services, pinpointing areas where sustainability efforts can have the most significant effect.

By combining these two methodologies, businesses can leverage their distinct strengths. e3value focuses on economic interactions, and LCA detailed environmental assessment to overcome the limitations inherent in using either method alone. This integration results in a more holistic and balanced framework that enables comprehensive evaluations of both economic and environmental factors. Such a framework supports more informed and strategic decision-making, ensuring that sustainability goals are met without compromising economic performance.

3.2.2 Stakeholder Needs

As established in the problem statement in Chapter 1, the integration of business network models and environmental impact assessments is essential for addressing the growing demand for sustainable practices within business networks. While the rationale for this integration and a review of existing methodologies have been thoroughly discussed in previous chapters, it is now critical to focus on understanding the stakeholders who will benefit from such integrated methods.

In this subsection, key stakeholders who stand to gain from this integrated approach are identified, and their specific needs and interests are examined. Given the business network context, stakeholders are not only within a single organisation but also extend

beyond individual businesses. Both internal and external stakeholders are increasingly required to balance economic performance with environmental responsibility.
The integrated approach will be especially beneficial for several key roles within businesses. Business Development Officers are usually tasked with driving growth and expansion[51]. As companies increasingly prioritise sustainability[25], the responsibilities of these stakeholders may shift accordingly. This necessitates their focus not only on economic aspects but also on other dimensions of sustainability, such as environmental impact. Therefore, they likely require an approach that promotes environmentally sustainable practices in addition to profitability.
One key stakeholder within a business is the Corporate Sustainability Officer, typically responsible for integrating sustainability into corporate strategy and operations[24]. They play a leading role in advocating for sustainable practices and need to demonstrate the business case for sustainability initiatives by showcasing both environmental and economic benefits. They also require effective methods to communicate that the business is both economically profitable and environmentally responsible. With an integrated approach, they can prove that a business model can be environmentally conscious without sacrificing profitability.
Supply chain officers are responsible for overseeing the movement of goods, services, and information throughout a company's supply chain[62]. They will also need to align with the company's goals and strategy. If the company places increased emphasis on sustainability, it will be necessary to monitor the entire supply chain to ensure it is green and sustainable. Furthermore, there must be a balance between cost efficiency and sustainability objectives. For those roles, utilising an integrated method that combines economic and environmental evaluations will be vital for monitoring sustainability and determining whether the associated costs are justifiable.
Investors, particularly those focused on ESG criteria, are increasingly concerned with how companies manage their environmental impact alongside their financial performance. Financial institutions offering green financing will also find value in a method that provides a comprehensive view of a company's environmental and economic outcomes. While they may not be interested in the integrated method itself, the results that show the economic benefit and environmental impact will be of great interest to them for making informed investment decisions.
In addition, governments and regulatory bodies are vital stakeholders responsible for enforcing environmental regulations and promoting sustainable development. An integrated approach that incorporates both economic and environmental assessments will be invaluable for these entities, ensuring that businesses adhere to legal and ethical standards. Governments may have a particular interest in public companies in which they have a share as they seek to ascertain whether the company will contribute to economic development. The insights derived from this integrated method, which includes both economic and environmental assessments, will be valuable for them to evaluate how businesses can support economic development while also advancing Sustainable Development Goals.
Finally, consumers who are increasingly mindful of sustainability are eager to learn about the results of environmental impact assessments carried out within business networks. While their primary focus may not be on economic factors, they are highly interested in the environmental sustainability of the products and services they select. Table 3.1 offers a summary of potential stakeholders and their respective goals.

Table 3.1: Summary of Stakeholders and Goals

Nr	Stakeholder	Goal
1.	Business Development Officer	Drive business's growth and expansion while supporting environmentally sustainable practices alongside profitability.
2.	Corporate Sustainability Officer	Embed sustainability into corporate strategy and operations, demonstrating the business case for sustainability by highlighting both environmental and economic benefits.
3.	Supply Chain Officer	Manage the flow of goods, services, and information efficiently while balancing cost efficiency with sustainability goals.
4.	Investor	Ensure companies manage environmental impact alongside financial performance, focusing on sustainability in investment opportunities.
5.	Government and Regulatory Body	Enforce environmental regulations, promote sustainable development, and ensure businesses comply with legal and ethical standards.
6.	Customer	Make informed purchasing decisions based on environmental performance and support products and services that align with sustainability goals.

3.3 Design Requirement

Several requirements are defined for combining both economic and environmental assessment methods. The requirements focus on functionalities that can produce an effect when applied to the context. In this case, the requirements focus on supporting informed decision-making for practitioners.
Functional Requirement :

1. Capability to represent all stakeholders involved in the ecosystem, activities that generate both economic value and environmental impact, along with the life cycle stage that is present in each actor, and the environmental consequences the business can produce (e.g., carbon footprint, water usage).
2. Capability to assess qualitatively and quantitatively economic value and environmental impacts for each actor and exchange within the value network.
3. Visualisation capabilities to represent the flow of economic and environmental impacts between actors in the value network.

Non-functional Requirement :

- The framework should be scalable to handle complex value networks with multiple actors and exchanges.
- Ability to adapt to different industries and various environmental impact categories and economic metrics.

4 TREATMENT DESIGN

During the treatment design phase, an artifact is designed. According to Wieringa, an artifact is created for a practical purpose and is intended to interact with the problem context to improve something within that context[74]. In this research, the artifact to be designed is a combined method for assessing economic value and environmental impact. With regards to this, the steps to develop the artifact are depicted in the Figure 4.1.

4.1 Initial Case Study

The first step aims to understand the current method and conduct economic and environmental impact analyses. The focus is on performing e3value and LCA to gain insight into how these methods can be combined, as well as the drawbacks of each method when conducted separately. The initial case comes from an e3value study, specifically the Foroba Blon, a community radio in Mali. A brief description of the case will be presented in the next section; additional information about the case can be found in the work by Bon et al.[9].

4.1.1 Case Description

The case description below is adapted from [9, 31].

> ”In Mali, community radio stations operate with varying levels of technological infrastructure. Some are state-funded and connected to the national broadcasting service ORTM, while others are privately funded or self-sustaining. These stations have different levels of access to computers and the internet, but all are within the coverage area of mobile phone networks, allowing for potential internet connectivity via mobile devices.
>
> The radio stations aim to implement a citizen journalism message system called Foroba Blon (FB). This system allows citizens to send voice messages to the radio stations via mobile phones. The stations can then retrieve these messages and broadcast them. This system streamlines the traditional process of writing messages on paper and reading them aloud on air by enabling direct voice message submissions and storage.
>
> This service involves several stakeholders, including customers (who create announcements), village reporters (who validate and forward announcements), radio stations (which broadcast the announcements), FB service providers (who pay for broadcasting services), telecommunication companies (which provide necessary phone connections), and listeners (who receive the announcements).

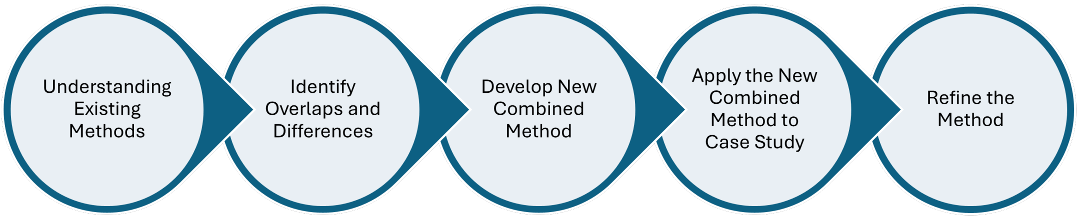


Figure 4.1: Development Steps

4.1.2 Economic Assessment Using E3value for Initial Case

In Chapter 2 of the thesis, the theory, basic concepts, and ontology of e3value are introduced. It also delves into the application of e3value but does not provide a detailed, step-by-step guide to conducting economic valuation using e3value. An article by Gordijn et al. was discovered, which offers a comprehensive approach to evaluating the financial sustainability of ICT services[31]. The article outlines six steps to evaluate financial sustainability:

1. Clearly state the idea[31].
   In this phase, a thorough analysis of the case's background and the complex processes involved will be conducted. Additionally, a thorough exploration of the business concept and its benefits will be undertaken. The needs will also be identified at this stage, and the actor relations involved in the business will be studied.

2. Represent the idea as an e3value diagram[31].
   Once the business understanding is established, the actors and market segments are defined, along with their respective needs and responsibilities. The explanation of economic value and the flow of economic value between actors follow. Finally, the e3value model is created. For this process, the e3value diagram is originally taken from the works of the author, and Figure 4.2 depicts the e3value model.

3. Assess economic sustainability from a qualitative viewpoint[31].
   This step focuses on evaluating the economic sustainability of the project through qualitative observations. The model will be assessed to identify any missing or underrepresented elements, aiming to understand potential limitations and opportunities for improvement. This step also involves analysing the revenue model to ensure long-term economic sustainability. Additionally, it will assess whether all the stakeholders involved in this business have more money flowing in than out in the long term.

4. Attribute the constructs in the e3value diagram with numbers[31].
   During this stage, numerical values are assigned to different elements of the e3value model to measure the economic aspects of the project. When using the e3value methodology to design a service, it's important to remember that the quantification is

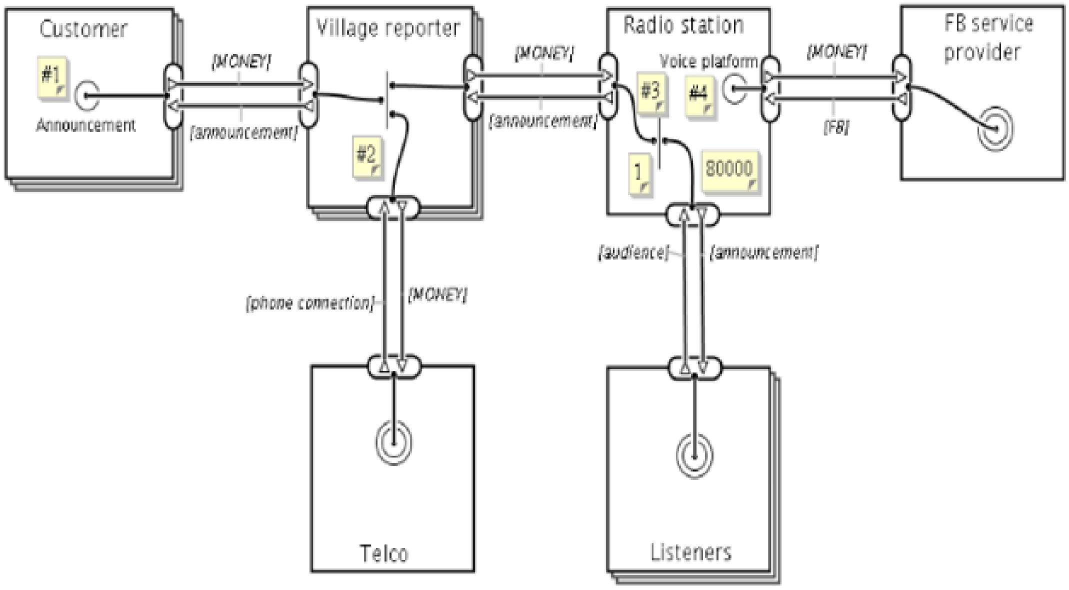


Figure 4.2: E3value of Foroba Blon Case [31]

always an estimate. If the assessment is conducted for an already functioning service, the quantification should be based on actual case numbers. Before beginning the quantification process, it's crucial to agree on the time frame for the e3value diagram. The quantification process involves three steps: quantifying the price of the service, quantifying the number of actors (as the notion of market segment represents a set of actors), and quantifying the number of customer needs.

5. Evaluate economic sustainability from a quantitative viewpoint[31].
Upon completion of the assessment of the economic value attribute, e3value tools were used to create value flow sheets for conducting a quantitative analysis of the e3value model. The net value flow sheet shows the net value flow within a specific time frame, representing a monetary unit for each value transaction. This guide is specifically designed to assess financial sustainability, emphasising the importance of positive cash flow for all actors in order to have a sustainable business idea. If an actor experiences negative cash flow within the agreed timeframe, the business may be considered unsustainable.

6. Refine the idea and e3value model[31].
The goal of this study is to evaluate the newly defined service using the e3value model. This step is crucial for further developing and refining the model to ensure it accurately represents the service and its value exchanges.

E3value Model and Economic Assessment from FB Case

In this particular model, there are six stakeholders involved: customers, village reporters, radio stations, FB service providers, Telco providers, and listeners. The customers, village reporters, and listeners are categorised as distinct market segments due to their essential roles as actors, each contributing economic value in their unique ways. The process commences with the customer's payment for the service, which is then passed on to the village

Table 4.1: Quantification of FB Service[31]

Price of the Service	
Announcement service (customer)	fCFA 1,500 per announcement
Announcement service (reporter)	fCFA 750 per announcement
Phone Call	fCFA 650 per announcement
FB service	fCFA 200,000 per announcement
Number of Actor	
Customer	2,550
Village reporter	85
Customer Needs	
Announcement (per customer per month)	1
FB Platform	1

Table 4.2: Revenue per Actor[31]

Actor	Revenue per actor (fCFA)
Village reporter	fCFA 3,000
FB service provider	fCFA 200,000
Telco	fCFA 1,657,500
Radio Station	fCFA 1,712,500
Customer	fCFA - 1,500
Listener	n.a.

reporter. Subsequently, the village reporter remunerates the radio station for message broadcasting and covers the expenses associated with the message transmission provided by Telco. Additionally, the radio station compensates the FB service provider for the messaging system service. Following this, the radio station delivers the message to the listener. While there is no direct economic exchange between the listener and the radio station, the audience itself represents the value that the radio station derives.

After defining the e3value model, the next step is to quantify it for sustainability assessment. This involves assigning numbers to construct the quantification. Based on the guidelines explained in the previous sub-chapter, three quantifications are needed. Table 4.1 displays the quantification of the service price, number of actors, and customer needs. The revenue that each actor then generated using e3value tools. Table 4.2 will present revenue per actor.

Based on the analysis and quantification, it is evident that this business primarily generates profits for telecommunication companies and radio stations. The price for the telecommunication services is quite standard. On average, one customer uses the service to send messages each month. The radio station benefits the most from this business model. While customers are the ones investing money, the cost of fCFA 1,500 is reasonable for them compared to directly approaching the radio station to broadcast their message. This is due to the expensive transportation costs and the potentially time-consuming nature of directly approaching the radio station. Additionally, considering the risk factor, the business scheme is reasonably preferable for customers.

4.1.3 Environmental Impact Assessment Using LCA for Initial Case

The assessment follows the steps of the LCA framework depicted in Figure 2.1. Typically, LCA evaluates the environmental impacts throughout the entire life cycle of a product or service, from raw material extraction to end-of-life disposal. In this case, the focus is on the community journalism radio system. Due to the difficulty of measuring the complete life cycle from raw material extraction to end-of-life, the emphasis is placed on the operational aspects of the community radio stations.

1. Goal and scope definition
   This study focuses on the environmental impacts, primarily CO2 emissions, of community radio stations in Mali that use message systems for citizen journalism. The scope of the study includes the acquisition of necessary equipment (hardware), the operational phase (usage of hardware and internet connectivity), and maintenance. The functional unit could be defined as "the provision of one month's worth of community radio announcements via the FB system.

2. Inventory analysis
   The process of establishing inventory data involves gathering detailed information on the inputs and outputs related to the community journalism radio system. As shown in the e3value model in Figure 4.2, there are six key actors involved: the customer, village reporter, radio station, telco, FB service provider, and listener. For economic evaluation, the revenues of all actors are quantified. However, the LCA will focus on the village reporter, radio station, and FB service provider. This targeted approach is due to the significant roles these actors play in the system's operational phase. Expanding the scope to include the telco and listener would make quantification difficult, as we have limited insight into the telco's business details and services. It's possible that this business uses the telco as part of its process, but for the telco itself, this business represents only a small portion of its overall operations. Table 4.3 lists the inventory analysis for the village reporter, radio station, and FB service provider. It provides information on the equipment used by the stakeholders, along with the necessary data for impact assessment.

3. Impact Assessment
   During the impact assessment phase, the goal is to quantify the environmental impacts identified in the inventory analysis. This involves measuring the emissions associated with the operation of the community journalism radio system using the data collected during the inventory analysis. The focus is on quantifying emissions from the operational activities of the village reporter, radio station, and FB service provider. This involves quantifying the emissions the equipment produces and translating energy use and total waste into CO2 equivalent. For example, assuming 83 village reporters, each with one mobile phone, the total environmental impact will be multiplied by 83. For the radio station, it is assumed there is one equipment for the computer, mobile phone, and broadcasting equipment. For the FB service provider, it is assumed there is one set of networking devices. Table 4.4 presents the impact of each stakeholder.

4. Interpretations
   In the interpretation phase, the results of the impact assessment are carefully analysed. By utilising all available data, the most reliable conclusions and recommendations can be formulated. The impact analysis shows that the emissions produced

Table 4.3: Inventory Analysis for FB Case

Hardware	:	**Mobile Phone**
CO2 from Production	:	50 kg CO2e
Lifespan	:	3 years
Monthly Energy Usage	:	7.2 kWh/ month
E-waste	:	0.2 kg/unit
Recycling Rate	:	50%
Hardware	:	**Computer**
CO2 from Production		500 kg CO2e
Lifespan	:	5 years
Monthly Energy Usage	:	48 kWh/month
E-waste	:	20 kg/unit
Recycling Rate	:	50%
Hardware	:	**Broadcasting Equipment**
CO2 from Production		1500 kg CO2e
Lifespan	:	10 years
Monthly Energy Usage	:	360 kWh/month
E-waste	:	100 kg/unit
Recycling Rate	:	50%
Hardware	:	**Server and Networking Equipment**
CO2 from Production		2000 kg CO2e
Lifespan	:	5 years
Monthly Energy Usage	:	360 kWh/month
E-waste	:	20 kg/unit
Recycling Rate	:	50%

are relatively low and acceptable. A typical household in the United States emits approximately 7.5 metric tons (7,500 kg) of CO2 per year, which averages to around 625 kg per month. The average global carbon footprint is about 4 metric tons (4,000 kg) of CO2 per person per year, equating to roughly 333 kg per month. Furthermore, it can be concluded that Village Reporter, with 131.138 kg CO2e/month, has relatively low emissions, aligning with sustainable living targets. Radio Station with 226.7548 kg CO2e/month has moderate emissions, somewhat higher but still below average household emissions. FB Service Provider with 393.5 kg CO2e/month has higher emissions, nearing the global average personal carbon footprint per month.

4.2 Development of New Combined Method

Following the completion of experiments using both methods, the primary focus is to analyse and pinpoint the strengths and weaknesses of each method. The aim is to identify any areas of overlap and distinct elements within the methods, which will then be used to develop a new, comprehensive approach for assessing both the economic and environmental impact.

Table 4.4: Impact Analysis for FB service

Village Reporter	
CO2 from Mobile Phone Production	1.39 Kg CO2e/month x 85 = 118.15 kg CO2e/month
CO2 from mobile phone energy usage	0.15 kg CO2e/month x 85 = 12.75 kg CO2e/month
CO2 from mobile phone e-waste	0.0028 kg CO2e/month x 85 = 0.238 kg CO2e/month
Total CO2e for village reporter	131.138 kg CO2e/month
Radio Station	
CO2 from Mobile Phone Production	1.39 Kg CO2e/month
CO2 from mobile phone energy usage	0.15 kg CO2e/month
CO2 from mobile phone e-waste	0.0028 kg CO2e/month
CO2 from Broadcasting Equipment Production	12.5 kg CO2e/month
CO2 from Broadcasting Equipment energy usage	180 kg CO2e/month
CO2 from Broadcasting Equipment e-waste	0. 0.42 kg CO2e/month
CO2 from Computer Production	8.33 kg CO2e/month
CO2 from Computer energy usage	24 kg CO2e/month
CO2 from Computer e-waste	0.17 kg CO2e/month
Total CO2e for Radio Station	226,7548 kg CO2e/month
FB Service Provider	
CO2 from server and networking Production	33.33 kg CO2e/month
CO2 from server and networking energy usage	360 kg CO2e/month
CO2 from server and networking e-waste	0.17 kg CO2e/month
Total CO2e for village reporter	393.5 kg CO2e/month

4.2.1 Evaluation of Previous Experiment

Following the completion of the prior experiment, several significant findings and observations emerged due to conducting e3value and LCA assessments separately.

- First, there was a lack of a holistic view. Potential interconnections between economic and environmental impacts were often missed, leading to incomplete decision-making data. When e3value, which focuses on the economic value network, and LCA, which assesses environmental impacts, are conducted independently, they provide disjointed insights. This separation hinders a comprehensive understanding of the overall impact of a product or service, limiting the ability to make fully informed decisions.
- Second, inefficiencies in data collection and analysis were evident. Separate assessments may require duplicate data collection efforts. Different methodologies and data sources used in e3value and LCA led to inconsistencies, making it difficult to align results. For instance, the economic analysis might cover a one-year timeframe, while the LCA might span only one month, resulting in inefficient data collection and potential data loss. An example of this inefficiency occurred when calculating CO2 emissions for village reporters; the intensive data collection for LCA overlooked the detail that there were 85 village reporters, a critical factor that significantly impacted the accuracy of the analysis.
- Issue with defining the scope and goals is experienced. Typically, the scope and goals for LCA are determined at the beginning. However, the nature of LCA, which does not specify who is responsible for what, can complicate this process. During the experiment for the FB case, it became evident that each stakeholder might define the goals and scope differently. In some instances, the goals, scope, and parameters to be measured were similar, but in others, there might be significant differences. Additionally, it is crucial to consider that stakeholders might be at different stages of the product life cycle, leading to further variations in scope and measurement.

These findings highlight the drawbacks of conducting e3value and LCA assessments separately. A combined method would address these issues by providing a holistic view, improving efficiency in data collection and analysis, and ensuring aligned and consistent objectives.

4.2.2 Development of Key Elements

It is important to define key components to connect economic and environmental assessments effectively. By identifying common key elements, one can create a framework to integrate and analyse economic and environmental data systematically. This will allow for a thorough evaluation, considering both environmental and economic aspects. These key elements also help to link value activities in the e3value model to environmental impact categories used in LCA, which is essential for accurately connecting economic activities to their environmental effects. Figure 4.3 lists the key elements that need to be defined for this combined method, while the explanation will be described below.

1. Actor Identification
   The e3value methodology provides a systematic approach for representing networked

business models. It includes actors such as enterprises and end-consumers. Identifying the specific actors involved in the business is a critical step that lays the foundation for developing a comprehensive assessment. This initial identification serves as the starting point for understanding the relationships and interactions within the business model, providing valuable insights for further analysis and optimisation.

2. Value Activity Identification
   Value activity is an integral part of the e3value methodology, although not all e3value models necessarily include value activities. Whether to include value activities depends on the modeller's discretion. However, in this context, defining value activities is essential as it helps to identify economic activities that result in costs or generate benefits. This identifying process is critical for connecting economic activities to life cycle stages, offering a clear depiction of how different activities influence both the economy and the environment. Through the definition of value activities, a more comprehensive understanding of economic transactions and their associated environmental impacts within each life cycle stage can be achieved. Value activity identification should be repeated for each defined actor.

3. Life Cycle Stage Identification
   In the context of the LCA process, there is no specific definition of a life cycle stage. However, it is crucial to define the life cycle stage for each identified actor. This identification is essential to assist the modeller in accurately defining the environmental impact they intend to measure. The life cycle stage could be different depending on the standards of a specific field; the life cycle stage for building and construction might be different from that of a retail business. It also varies for each life cycle model. The common life cycle stage for a cradle-to-grave life cycle model includes raw material extraction, manufacturing and processing, transportation, usage and retail, and waste disposal.

4. Economic Value and Environmental Impact Exchange
   When it comes to the e3value model, it's essential to define the value flow, encompassing economic values such as money, products, or services offered. To provide a more comprehensive assessment, it's also crucial to illustrate the environmental impact associated with these value exchanges. This includes scenarios where environmental impacts, such as emissions or waste, are transferred between actors. By incorporating environmental impact exchanges, we can more accurately represent benefits and drawbacks from economic and environmental perspectives. This holistic view helps identify opportunities for reducing environmental burdens while maintaining economic value.

5. Assessment Metrics Definitions
   Defining the metrics for economic assessment and environmental impact is crucial for measuring and evaluating performance in these areas. These metrics ensure consistency and comparability in assessments. Economic metrics could cover costs, revenues, profit margins, and return on investment, while environmental impact metrics might include carbon footprint, water usage, waste generation, and energy consumption. Clear and precise definitions of these metrics are essential for accurate and meaningful analysis, helping stakeholders make well-informed decisions based on comprehensive and reliable data.

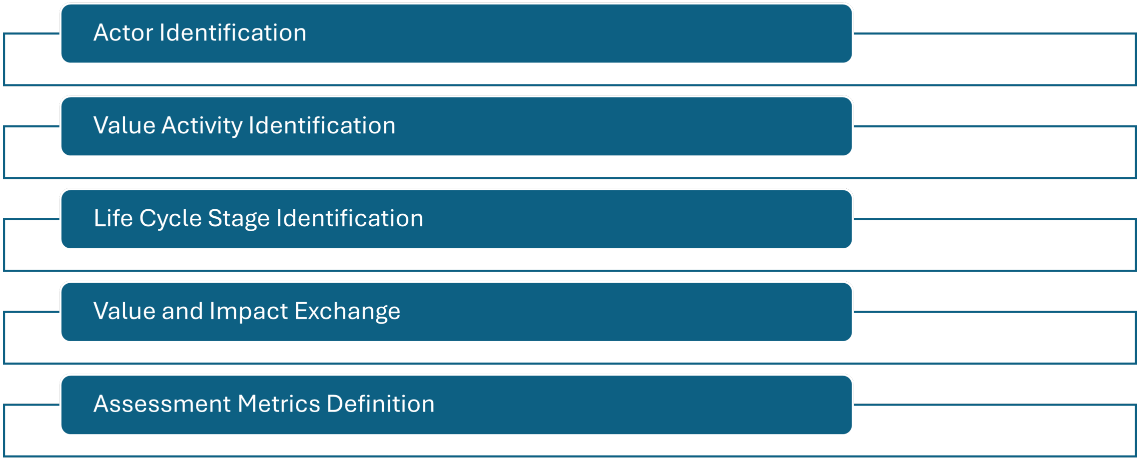


Figure 4.3: Key Element of Combined Method

4.2.3 Guideline of New Method

This research aims to not only define essential elements but also establish guidelines for evaluating business network models from both economic and environmental standpoints. Figure 1 illustrates the step-by-step assessment process. Each stakeholder should have their own specific goal and scope. However, within the business network, overarching goals for the entire business ecosystem will exist. Therefore, the initial step of defining the scope and goal should focus on establishing the network's overall goal and scope. Then, it is crucial to iterate each step of the guidelines for every stakeholder involved. For a more detailed explanation of the step-by-step guidelines, please refer to the following.

1. Define Scope and Goal
   The initial steps from both LCA and e3value methodologies are integrated in this phase. It is crucial to clearly outline the assessment goals, including specific desired economic and environmental outcomes. The scope must be established by defining the boundaries of each stakeholder in the business network, along with specific measurement criteria and the timeframe for measurement. In LCA, the scope and goal definition serve to determine what is to be measured, what is excluded from measurement, and the measurement method. BM-LCA introduces innovation by expanding the goal and scope definition with a descriptive phase (originating from LCA) and a coupling phase, where it is augmented with a functional unit of economic aspects such as profit, cost, and revenue[12]. This step is an extension of LCA, providing a descriptive definition of the environmental and economic aspects.

2. Modelling and Visualisation
   In this step, you will create an initial e3value model to illustrate the business network and its value exchanges using e3tools. It is important to also include environmental aspects in the e3value model. As business models usually change over time, this step allows for continuous improvement of goals and scope. Key elements such as actors, value activities, and life cycle stages can be adjusted during this process. Since LCA does not have a visual representation, various mappings are defined to incorporate environmental aspects into the e3value model.

   - Life cycle stages will be presented as value activities, differentiated by using a green border colour. This approach is taken because the representation of value

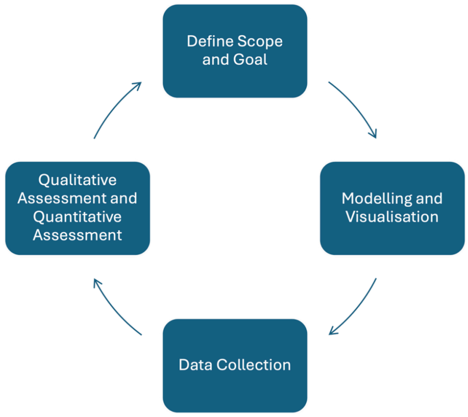


Figure 4.4: Guideline of Combined Method
The designed artifact will undergo testing and demonstration using a specific case to assess its utility.

activities and life cycle stages are quite similar, and despite some overlap, it is important to define them to gain a more holistic view.

- Environmental impacts for each actor will be annotated within the e3value model to present their environmental implications clearly.
- Impact Exchange is visualised like a value exchange, with the modification of a green line. Usually, the line is blue for economic value exchange.

3. Data Collection
This process involves merging step 4 from Gordijn et al.[31], which is to attribute the constructs in the e3value diagram with numbers, and inventory analysis from LCA[1]. This process involves gathering comprehensive data on economic transactions such as costs, number of actors, and any additional data to quantify economic quantification, depending on the defined scope. Additionally, this process should involve an inventory analysis to collect detailed environmental data, such as emissions, waste generation, and energy consumption that occur because of the business operation. This ensures that both economic and environmental data are systematically collected and documented for further analysis. The inventory analysis can be obtained from the LCA database, such as eco-invent, or by referring to scientific papers that have conducted an LCA. Doing an LCA can be data-intensive, especially for a larger scope of business.

4. Qualitative and Quantitative Assessment
This step will include steps 3 and 5 from Gordijn et al. It will also involve adding the impact assessment and interpretation from LCA since sometimes the interpretation is also done simultaneously in the impact assessment. The term assessment can be defined in a broader sense, so all the steps will be carried out here.

Upon defining the key elements and establishing step-by-step guidelines, the method undergoes continuous refinement. Figure 4.5 showcases the latest iteration of the integrated method.

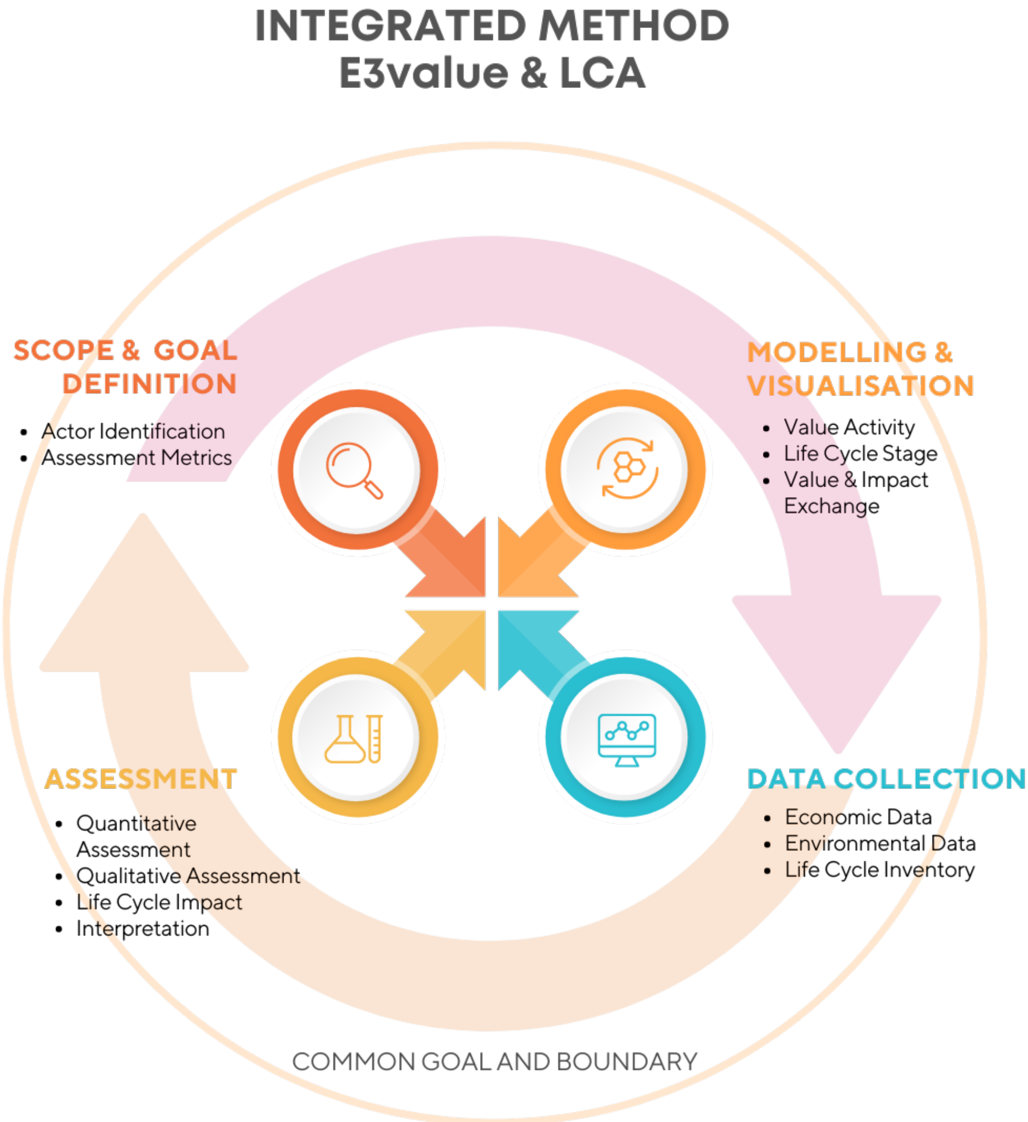


Figure 4.5: Integrated Method

4.3 Demonstration of New Method

The designed artefact will be tested and demonstrated using a specific case to see its utility. The following will include a description of the case study and the application of a combined method utilising it. In this section, the guidelines defined in the previous section will be implemented in the case study. The identification of key elements will be conducted along with the following guidelines.

4.3.1 Description of Second Case Study

The case focuses on the solar power plant business model in Indonesia, with the focal actors being the electricity provider and the customer. Additionally, several other actors are involved to provide a comprehensive view of the business ecosystem. The case is based on real situations within the solar power plant business, but certain aspects, such as data, are reliant on assumptions formulated by the researcher based on available references.

Background of the Case

Indonesia has set ambitious targets to achieve 23% renewable energy in the national energy mix by 2025 and 44% by 2030, as stated in the Indonesian National Energy Plan[54]. However, as of the end of 2023, the actual realisation of the renewable energy mix has only reached around 13.1%, showing a slight increase from 12.3% in 2022[23, 17]. Indonesia has significant potential for solar energy, but its current utilisation is quite limited. The government is currently prioritising the advancement of solar power plant development in order to fulfil specified targets.
Rooftop solar power plants are intermittent, meaning that electricity production is not always consistent and can fluctuate depending on weather conditions and time of day (day/night). As a result, the reliability of electrical systems that rely on solar power needs to be carefully considered. The installation of solar power plants is governed by various regulations to support the development of renewable energy and ensure safety and efficiency standards. Furthermore, the government is actively working on integrating rooftop solar power plants into the national electricity network.
A business needs a license to provide electricity for public use, known as IUPTLU, issued by the Indonesian government through the Ministry of Energy and Mineral Resources. This permit covers various activities, including generation, transmission, distribution, and electricity sales. Solar power plants can operate as either an on-grid system (connected to the public electricity grid) or as an off-grid standalone system. The regulation governs the installation of solar power plants that are connected to the IUPTLU holder's electricity network[48]. The regulation generally applies to customers of IUPTLU holders, with PT PLN being used as an example in this case. Below are the highlights of the regulations for the installation of solar power plants.

- Quota System: The quota system is implemented to ensure the reliability of the electricity system. Its purpose is to prevent the number of solar power plants connected to the grid from exceeding the capacity that can be handled by the PLN system, thereby maintaining the overall reliability of the electricity supply[20].

- Installation Capacity: The capacity for installing solar power plants is not limited, but it depends on the availability of PLN quotas. This means that the capacity of solar power plants can exceed 100% of the power installed by PLN, as long as the PLN quota allows for it[48, 37].

- The export-import mechanism for electricity is being eliminated. This means that excess electrical energy produced by solar power plants will no longer be factored into customers' electricity bills[48]. As a result, PLN, the electricity company, will not have to compensate customers for any surplus electricity. However, customers will use less electricity from the PLN source as they will be using solar power.
- Capacity Fees: Capacity fees are waived for all types of PLN customers. This is expected to reduce the costs that must be incurred by solar power plant users[37].
- Incentive: Even though the export-import scheme has been abolished, the government still provides incentives for installing solar power plants, such as the elimination of advanced meter procurement costs, capacity fees, and other costs generally charged to customers[48].

PLN will submit an indication of the quota for solar power systems that can be developed per region every five years to the Ministry of Energy and Mineral Resources for evaluation[20]. In accordance with regulations, customers who intend to install a solar power plant must acquire a permit from PLN, regardless of whether they meet the approved quota. Additionally, as they will be connecting to the PLN grid, they will require a meter that is capable of switching to the PLN grid when not utilising solar power.

Business Scheme

ICON+ is a subsidiary of PLN that operates in the telecommunications services, information and technology sectors. The company is exclusively authorised to utilise electricity assets from PLN and is entrusted with developing the solar power plant business. ICON+ offers a comprehensive solution for the solar power plant system service, covering every installation stage from initial technical analysis and engineering, investment, procurement, construction, integration with the PLN Grid, operational phase, and the subsequent transfer of ownership at the conclusion of the contractual period.
ICON+ is dedicated to meeting its customer base's diverse needs, including industries, retailers, and households. They offer a range of options for installing solar panels, including on-grid, off-grid, and hybrid systems. Customers have the freedom to select from multiple payment options. These options include:

1. Direct investment: Customers could make a one-time payment covering the entire investment fee at the beginning of the contract.
2. Leasing: This option involves a financial company paying the initial investment, with the customer subsequently making instalment payments to the financial company.
3. Managed services: ICON+ offers a rental system to customers with a 10-year contract period. At the end of the rental period, the PV Rooftop becomes the customer's property.

ICON+ ensures that all technical equipment adheres to the necessary standards and effectively manages all contractual and administrative requirements, including securing the required permits from PLN for the installation of solar power plants. Additionally, ICON+ forges strategic partnerships with EPC (Engineering, Procurement, and Construction) companies to develop and operate solar power plant systems. These partners are responsible for the installation, ongoing operation, and maintenance of the solar power systems, while sourcing materials from trusted manufacturers. Furthermore, ICON+ integrates

digital solutions, such as dashboards and monitoring tools, to provide customers with enhanced support and valuable insights.
In this case, ICON+ is offering its comprehensive solar power plant solutions to PLN customers in the industrial category. Specifically, the focus is on TVS, a manufacturing company in Indonesia, which is considering the installation of a 1,020 Kilowatt peak (kWp) solar power plant. ICON+ will deliver a tailored, complete solution to meet TVS's specific energy requirements.

4.3.2 Define Scope and Goal

In this instance, the primary focus will be on installing a solar power plant integrated into the grid. One specific company will be used for customers as an example. Due to the range of payment options provided by ICON+, the emphasis will be placed on direct investment in this particular case for practicality.
As stated in the guidelines' description, every step needs to be iterated for each actor. Therefore, when defining the scope and goal, one important key element that needs to be defined is the list of actors. At this stage, it is also important to define the goals and scope for each stakeholder involved in the business ecosystem. In LCA, defining goals and scope is related to environmental impact. Here, we will expand it by also defining the scope and goals for economic value. Another key element that needs to be identified in this step is the metric for economic and environmental assessment.
Before defining the scope and goals for each individual actor within the ecosystem, it is essential to first establish the overarching objectives and scope for the entire business network. The ecosystem must operate with a unified goal. In this context, the primary objective is to enhance sustainability by fostering a solar power business model that delivers value to all stakeholders while minimising dependence on non-renewable resources.
The scope of the assessment will centre on the solar power plant itself. This evaluation will cover both the economic value and environmental impact related to the solar power plant, including aspects such as business profitability and the environmental footprint of solar panel production and usage. While stakeholders may have diverse products and services, this study will focus solely on those elements directly related to the solar power plant. For example, although the study may involve PLN customers from the manufacturing sector, it will not analyse the specifics of their manufacturing products. Instead, it will concentrate on evaluating electricity usage and the impact of the solar power plant installation.
The next step is to define the scope and goals for each stakeholder. Below is the list of actors, along with the scope and goal definitions.

1. PLN
   The state-owned electricity company holds a significant portion of the electricity market. As part of its efforts to expand the country's renewable energy sources, PLN aims to enter the solar power plant sector to speed up the construction and integration of renewable energy into the existing energy mix. Although the solar power plant business will be handled by its subsidiary, PLN is still involved to some extent and may receive or provide benefits to other stakeholders.

   - Goal: To identify the economic benefits and drawbacks generated by a solar power plant business scheme. Additionally, since PLN mostly relies on non-renewable energy for power generation, the environmental impact of this business scheme can be discovered.

- Scope: Measure the economic value and environmental impact of conventional power generation and how it will be decreased with the installation of a solar power plant
- Assessment Metrics: Global warming impact from conventional power plant, reduced emission from renewable energy installation, reduced revenue from the solar power plant business and reduced investment, and revenue from giving the permit for solar power plant.

2. ICON+
The PLN subsidiary will manage the solar power plant business. As the legal entity with the authority to manage electricity assets, ICON+ offers an end-to-end solution to its customers in this business scenario. ICON will partner with another party to implement the solar power plant at the customer's site.

    - Goal: To identify the economic benefits of a solar power plant business scheme and identify if there is a direct environmental impact from this business scheme.
    - Scope: Assess the economic value and environmental impact of traditional power generation, excluding ICON+ business activities. The focus is on services provided for solar power plants.
    - Assessment Metrics: Revenue, Profit, Reduced emission(if any).

3. TVS as Customer
In this instance, we will use TVS as an example of a customer. TVS is a multinational motorcycle manufacturing company. We will not delve into the TVS business model, as this case study will focus on the solar power plant business. We use TVS as an example of a PLN customer who wants to implement a solar power plant using the services provided by ICON+.

    - Goal: To identify the economic benefits and investment required for a solar power plant, as well as to assess the environmental impact of this business scheme.
    - Scope: Evaluate the economic value and environmental impact of solar power plant generation. The assessment will only focus on electricity usage from PLN and solar power plants, excluding the customer's core business process.
    - Assessment Metrics: ROI, Payback period, annual saving from electricity bill, reduced emission, and energy mix.

4. EPC Partner
ICON+ does not have sufficient capability to manage the technical aspects of the solar power plant business. As a result, they have entered into partnerships with several entities to ensure the smooth operation of the business. Although multiple EPC partners can exist, for simplicity, we will assume that there is only one EPC partner.

    - Goal: To identify the economic benefits and drawbacks generated by the installation and construction of a solar power plant business.
    - Scope: Measure the economic value and environmental impact of the construction and installation of a solar power plant.
    - Assessment Metrics: Global warming impact from construction and installation, and profitability of this business.

5. Manufacturer
   The manufacturer is the entity that provides the materials for a solar power plant, including the solar panels, electrical components such as inverters and wiring, the mounting system, and the protection box. However, for simplicity, we will focus on just one entity that produces solar panels.

   - Goal: To identify the economic benefits and drawbacks generated by producing solar panels.
   - Scope: Measure the economic value and environmental impact of conventional production of the solar panel specifically for the case.
   - Assessment Metrics: Global warming impact from the production of solar panels and profitability from this business.

4.3.3 Modelling and Visualisation

Several key elements should be defined before modelling and visualisation can be created. The previous step already defined two key elements: actors and assessment metrics. Here, we will define the value activity and life cycle stage. The summary of identified key elements is also provided in Table 4.5

- PLN
  As the electricity provider, PLN's main responsibilities include power generation, billing and metering, and authorisation of solar power plant installations. Although the first two activities are not directly related to solar panel systems, they are connected in terms of the benefits of using solar panels. PLN's life cycle includes operational phases of power generation, transmission, and distribution. In this case, we will focus on the operational phase of power generation to measure how much the solar power plant will reduce the emission of the current electricity business.
- ICON+
  ICON+ will play a key role in this phase of the business. They will manage the sales of solar power plant services, handle customer contracts, arrange partnerships to outsource technical work, and ensure the standard and quality of the solar power plant. Leveraging their expertise in IT services, they will also provide digital infrastructure for the solar power plant system, including a comprehensive dashboard for monitoring electricity usage and generation.
- TVS
  As we will not be focusing on the TVS manufacturing business, TVS's main value activity will be consuming electricity from PLN and also acting as electricity generators for themselves. The life cycle stage defined for this customer is the usage phase.
- EPC
  The actor is involved in EPC activities related to installing, operating, and maintaining solar power plants. These activities encompass the life cycle stages of construction, installation, and ongoing operation and maintenance of the solar power plants.
- Manufacturer
  The manufacturer's main activity involves the production of solar panels, with the

life cycle stage encompassing the manufacturing process and potentially the end-of-life of the solar panel material.

The next key element that should be defined is value and impact exchange.

- Value Exchange Between PLN and Customer
  PLN supplies electricity to customers through its generation and distribution network. In exchange, customers pay electricity fees. PLN also provides PV (photovoltaic) permits, which allow customers to install solar energy systems. This leads to a decrease in kWh usage from the grid, reducing electricity costs and emissions for customers. The impact of the exchange between PLN and the customer is caused by emissions from conventional electricity generation and resource depletion.

- Value Exchange Between PLN and ICON+ PLN, the parent company, provides legal and strategic support to ICON+. Although PLN is not directly involved in the sale of PV systems and management contracts, ICON+ still needs to manage the legal matters related to customer solar power plant installation permits with PLN. In exchange, ICON+ will provide legal fees. This relation has No direct environmental impact.

- Value Exchange Customer and ICON+
  Customers purchase PV systems and digital services from ICON+. These systems allow customers to generate their own electricity, reducing reliance on PLN's conventional power and contributing to lower emissions.

- Value Exchange TVS and EPC Partner TVS do not realise the relationship because all services are provided by ICON+. However, EPC partners still have services to offer to customers. The economic exchange occurs between EPC Partners and ICON+.

- Value Exchange EPC Partner and Manufacturer EPC Partners procure valuable PV materials from manufacturers for their projects. Manufacturers supply these materials and support EPC Partners in installation and maintenance processes.

After gathering all the key elements, the modelling process is conducted. As the model continues to evolve, some refinement will be made to the identified key elements, goals, and scope. The model of the solar power plant business is depicted in Figure 4.6.

4.3.4 Data Collection

When analysing economic data, it is essential to gather diverse information to assess each party's economic value. Initially, we must delve into PLN's revenue models, particularly their electricity selling model for TVS, a customer. It is imperative to scrutinise the electricity tariff applicable to TVS, which, according to the latest data, amounts to IDR 1,644.52 per Kilowatt hour (kWh)[56], as TVS falls under the industrial category.
To quantify the revenue generated by PLN through the sale of electricity to TVS, it is crucial to estimate TVS's average electricity usage. The manufacturing sector in Indonesia is renowned for its substantial energy demand driven by large-scale production needs[47]. Considering global benchmarks and the nature of industrial activities, high daily electricity consumption in industrial hubs like TVS is anticipated. Assuming a daily electricity consumption of 5,000 to 6,000 kWh[67], this translates to an estimated monthly consumption of 150,000 to 180,000 kWh, reflecting the substantial energy requirements necessary to support continuous production and operational efficiency in such industrial settings.

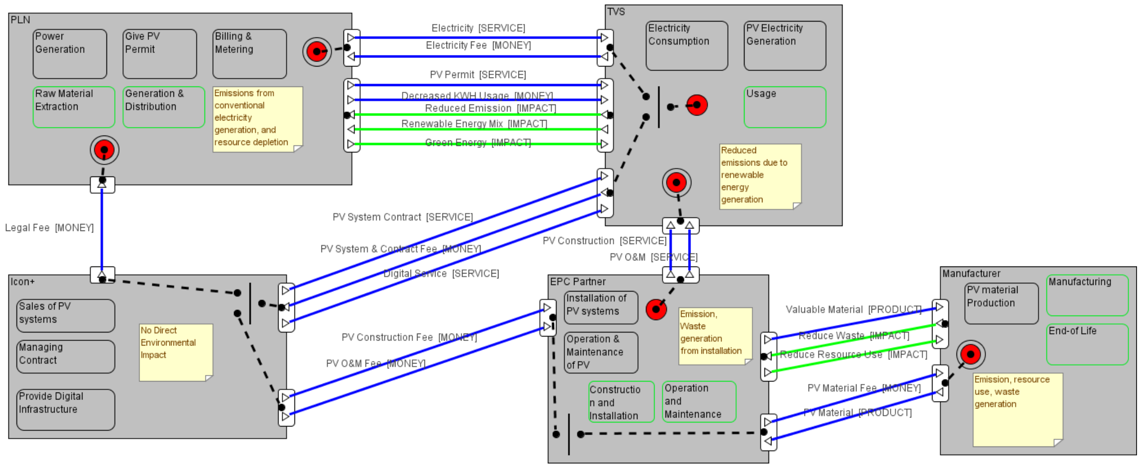


Figure 4.6: PVR Case Model

Table 4.5: Summary of Actors, Value Activity, and Life Cycle Stage

Actor/ Market Segment	Value Activity	Life Cycle Stage
PLN	Power Generation, Authorise Permit, Billing and Metering, Providing Advance Meter	Raw Material Extraction, Generation and Distribution
ICON+	Selling Solar Power Plant Service, Managing Contract, Providing Digital Infrastructure, Quality Assurance and Standard	No Defined Life Cycle Stage
TVS	Consuming electricity from PLN, Generating electricity from Solar Power Plant	Usage
EPC Partner	Installing Solar Power Plant System	Construction and Installation, Operation and Maintenance
Manufacturer	Producing Solar panel	Manufacturing, End of Life

Table 4.6: Summary for Economic Data

Parameter	Measurement	Value
PLN Electricity Tariff per kWh	IDR	1644.52
TVS Average Monthly Electricity Consumption	kWh	150,000 - 180,000
Provisional Installation of Solar Power Plan of TVS	kWp	1,020
Estimated Generated Electricity from 1020 kWp Solar Panel per Month	kWh	124,150
PV Module Price per Watt	IDR	10,137
PV Module Price for 1020 kWp	IDR	10,339,740,000
Solar Panel Installation Cost for 1020 kWp	IDR	2,067,948,000
Solar Panel Permit for 1020 kWp	IDR	310,192,200

Additionally, TVS is planning to install a solar power plant with a capacity of 1,020 kWp. The solar power plant is estimated to produce approximately 1,640,220 kWh (or 1.64 GWh) of electricity annually, assuming an average solar irradiance of 5.5 kWh/m^2/day and a performance ratio of 0.8, resulting in an approximate generation of 124,150 kWh per month.

However, the installation of a solar power plant necessitates a significant investment. ICON+, a subsidiary of PLN, offers TVS a service for 1020 kWp for complete support prior to annual operation support. ICON+ must collaborate with PLN to obtain the permit to install the power plant. Moreover, they need to engage with an EPC partner to install the solar panels.

Installation of a solar power plant entails not only solar panels but also other components such as inverters, wiring, and others. For simplicity, in this case, we will focus on the PV module. Assuming the use of Tier 1 Monocrystalline Half Cell Panels with ± 20% Efficiency and a cost per watt of USD 0.625 to USD 0,72, equivalent to IDR 10,137 and IDR 11,678[64], the estimated cost for 1,020,000 watts is IDR 10,339,740,000 to IDR 11,912,580,000.

Furthermore, considering the cost of installation, assuming an average installation cost of 20% of the system cost[33], which amounts to IDR 2,027 per watt. The installation cost for a 1020 kWp system would total IDR 2,067,948,000. Additionally, there is a fee to be paid to PLN for a permit, estimated at 3% of the solar system cost itself[33], totalling IDR 310,192,200. The summary of the economic data is included in Table 4.6.

We also need to examine the environmental impact of PLN electricity generation. As the customer is based on Java Island, we will focus on the Jawa-Madura-Bali Grid, which supplies electricity to TVS located in Karawang, West Java. As part of the Life Cycle Assessment (LCA), we need to conduct inventory analysis. Since this case study involves a wide scope of electricity generation, we will utilize an existing study that has already conducted LCA related to this study.

A study conducted by Nugroho et al. performed a comprehensive Life Cycle Assessment of the Indonesian Electricity Grid, specifically focusing on the Jawa-Madura-Bali grid. This study serves as a reference point for the research. The Life Cycle Assessment was conducted using a functional unit of 1 kWh of electricity generated and transmitted in the distribution line in the Jamali grid network in 2018[46]. The system boundary used in this study was cradle-to-gate, covering fuel production and transportation, electricity generation, and electricity distribution[46].

Table 4.7: Revenue for Each Actor

Actor	Description	Currency	Revenue
Customer	Initial Investment of 1020 kWp Solar Panel	IDR	-14,000,000,000
ICON+	Solar Panel service provider	IDR	1,282,119,800
PLN	Solar Panel Installation Permit for 1020 kWp	IDR	310,192,200
EPC Partner	Solar Panel Installation for 1020 kWp	IDR	2,067,948,000
Manufacturer	PV Module for 1020 kWp	IDR	10,339,740,000

The environmental data required for this case includes the LCA for monocrystalline solar cells. Notably, Rao et al. have conducted a relevant study on this topic. Therefore, we will not extensively cover the LCIA of the solar panel itself. A comprehensive cradle-to-grave life cycle assessment has been performed to assess the environmental impact in terms of energy payback time, greenhouse gas (GHG) emissions, and the net energy ratio of solar cells using monocrystalline material[57]. According to the International Energy Agency(IEA), the greenhouse gas emission of monocrystalline is 35.8 g CO2e per kilowatt-hour of electricity[6], and we will use this data to quantify the economic impact of PV production.
The data needed for the installation of a PV module depends on the installation location, as the transportation of the solar panel module needs to be calculated for the specific site. Since the exact information about the site or the PV producer does not exist currently, we are unable to obtain precise data on the environmental impact of the solar panel installation.

4.3.5 Qualitative and Quantitative Assessment

Based on the collected data, we will calculate the net cash flow for each stakeholder in this business model. In this case, the assumption of solar power plan service offered by ICON+ to customers is around IDR 14,000,000,000. Table 4.7 presents a straightforward calculation of the revenue that each actor received. Next, we aim to delve into the assessment of each actor.
First, let's focus on two key actors: the customer and PLN. The customer is responsible for the initial investment. The cost of installing a solar power plant is substantial and directly related to the amount of electricity generated. It's crucial to evaluate how this investment benefits the customer. We will analyse the operational costs associated with the installation of the solar power plant to determine its value for the customer. This analysis will involve quantifying annual savings, payback period, ROI, and NPV. Initially, we need to calculate the electricity costs before installing the solar panels.

$$Average\ Monthly\ Usage = (150,000 + 180,000)/2 = 165,000\ kWh \tag{4.1}$$

$$Monthly\ Electricity\ Cost = 165,000 \times 1,644.52 = IDR\ 271,341,300 \tag{4.2}$$

$$Annual\ Electricity\ Cost = 271,341,300 \times 12 = IDR\ 3,256,095,600 \tag{4.3}$$

It is also essential to quantify the anticipated cost savings resulting from the implementation of a solar power plant.

$$Shortfall\ \ in\ \ Monthly\ \ Usage = 165,000{-}124,150 = 40,850\ \ kWh \tag{4.4}$$
$$Monthly\ \ Cost\ \ for\ \ Shortfall = 40,850{\times}1,644.52 = IDR\ \ 67,146,622 \tag{4.5}$$
$$Annual\ \ Cost\ \ for\ \ Shortfall = 67,146,622{\times}12 = IDR\ \ 805,759,464 \tag{4.6}$$
$$Annual\ \ Savings = 3,256,095,600{-}805,759,464 = IDR\ \ 2,450,336,136 \tag{4.7}$$

Then we need to calculate the operational cost before installation and subtract the operational cost after installation.

$$Annual\ \ Savings = 3,256,095,600{-}805,759,464 = IDR\ \ 2,450,336,136 \tag{4.8}$$
$$Payback\ \ Period = 14,000,000,000/2,450,336,136 = 5.71\ \ years \tag{4.9}$$

Considering the extended longevity of solar panels, averaging approximately 25 to 30 years[63], an estimate of a 25-year return on investment will be utilised for the purpose of assessing the feasibility of installing a solar power plant.

$$Total\ \ Savings = 2,450,336,136{\times}25 = 61,258,403,400 \tag{4.10}$$
$$Net\ \ Profit = 61,258,403,400{-}14,000,000,000 = 47,258,403,400 \tag{4.11}$$
$$ROI = (47,258,403,400/14,000,000,000){\times}100 = 337.56\% \tag{4.12}$$

Based on these calculations, investing in the solar power plant seems highly beneficial, offering substantial long-term savings and a relatively short payback period. However, we also need to consider the environmental impact. Before installing the solar panels, the customer relied 100% on PLN electricity. The customer is located on Java Island, which is supplied through the Jawa-Madura-Bali grid. Approximately 89% of the energy supplied is non-renewable, while 11% is from renewable sources. This data represents the energy source for the customer as well. The initial energy mix before the customer installs the power plant is the same as the PLN energy mix for the Java grid. The calculation of the energy mix based on their usage is defined below.

$$Non-Renewable\ \ Energy : 165,000{\times}89\% = 146,850\ \ kWh \tag{4.13}$$
$$Renewable\ \ Energy : 165,000{\times}11\% = 18,150\ \ kWh \tag{4.14}$$

After installing a solar power plant, the energy mix needs to be recalculated. We must calculate the remaining electricity supply from PLN and the amount of electricity generated by the solar power plant. Here are the details of the energy mix generated from the remaining grid.

$$Energy\ \ from\ \ Grid : 165,000\ \ kWh - 124,150\ \ kWh = 40,850\ \ kWh \tag{4.15}$$
$$Non-Renewable\ \ Energy\ \ from\ \ Grid : 40,850\ \ kWh{\times}89\% = 36,356.5\ \ kWh \tag{4.16}$$
$$Renewable\ \ Energy\ \ from\ \ Grid : 40,850\ \ kWh{\times}11\% = 4,493.5\ \ kWh \tag{4.17}$$

The total energy mix in kWh for the customer after the solar power installation is outlined below:

Table 4.8: Impact Assessment of Jawa-Madura-Bali Grid

Impact Category	Result
Global Warming Potential (GWP)	1.06 kg CO2-eq
Acidification Potential (AP)	$5.89 \times 10^-3kgSO2 - eq$
Eutrophication Potential (EP)	$2.62 \times 10^-3kgPO4^3 - -eq$
Photochemical Oxidation Potential (POX)	$4.08 \times 10^-3kgNMVOC - eq$
Abiotic Depletion Potential (ADP)	$2.30 \times 10^-5kgSb - eq$
Abiotic Depletion Potential – Fossil Fuels (ADF)	11.58 MJ
Water Scarcity Footprint (WSF)	$3.76 \times 10^-2m^3$

$$Non-renewable\ \ Energy : 36,356.5\ \ kWh \tag{4.18}$$

$$Renewable\ \ Energy : 124,150\ \ kWh\ \ (solar) + 4,493.5\ \ kWh\ \ (grid) = 128,643.5\ \ kWh \tag{4.19}$$

Following the installation of the solar power plant, we will be able to calculate the percentage of renewable energy generated.

$$Percentage\ \ of\ \ Renewable\ \ Energy : (128,643.5kWh/165,000kWh) * 100\% = 77.93 \tag{4.20}$$

After installing the solar panels, the customer's renewable energy mix increased from 11% to approximately 77.9%, greatly reducing reliance on non-renewable energy sources.
We are also interested in determining the reduction in emissions resulting from the installation of solar power plants. To quantify this reduction, we first need to understand the emissions from conventional electricity generation, as customers currently rely on the PLN supply. Additionally, we need to evaluate the emissions from using the solar power plant. According to Rao et al., the emission caused by the solar power plant in the usage phase is zero[57].
We will not delve into the details of quantifying the emissions, as we will utilise the findings of the study by Nugroho et al [46]. The results of the LCA study of 1 kWh of electricity distributed in the Jawa-Madura-Bali grid will be presented in table 4.8. 1 kilowatt-hour (kWh) of electricity production results in 1.06 kilograms of carbon dioxide equivalent (CO2eq) emissions. We will proceed to quantify the global warming potential resulting from the electricity consumption of the customer, specifically TVS.

Emissions Before Solar Power Plant Installation

$$165,000 \times 1.06 = 174,900\ \ kg\ \ CO2e\ \ per\ \ month \tag{4.21}$$

Emissions After Solar Power Plant Installation

$$40,850 \times 1.06 = 43,301\ \ kg\ \ CO2e\ \ per\ \ month \tag{4.22}$$

Reduction in Emissions

Table 4.9: Economic Value and Environmental Impact for Customer

Metric	Value
Economic Value	
Annual Savings (IDR)	2, 450, 336, 136
Payback Period (years)	5.71 years
ROI 25 years (%)	337.56
Environmental Impact	
Energy Mix	
Renewable Energy (%)	77.9%
Non-Renewable Energy (%)	22.1%
Annual Reduced Emissions (Kg CO2-eq)	1, 579, 188

$$40,850 \times 1.06 = 43,301 \ \ kg \ \ CO2e \ \ per \ \ month \tag{4.23}$$

Yearly Reduction in Emissions

$$131,599 \times 12 = 1,579,188 \ \ kg \ \ CO2e \tag{4.24}$$

In summary, the economic value and environmental impact generated by this business scheme, particularly for the customer, are detailed in Table 4.9. Upon analysing the quantified economic and environmental aspects, it can be concluded that the investment in this scheme is beneficial for the customer, given the relatively short payback period. Furthermore, the scheme's significant environmental impact can notably contribute to emission reduction.

The solar panel industry is negatively impacting PLN's economic outlook. As more customers install solar panels, their dependence on PLN's electricity decreases, leading to reduced revenue for the company. When comparing the revenue losses due to reduced electricity sales with the costs of permits and the revenue generated from ICON+, PLN's subsidiary involved in the solar power sector, it becomes evident that these measures are insufficient to offset the revenue losses. Despite this, PLN retains significant leverage by controlling the approval process for connecting solar power plants to the national grid. This authority allows PLN to regulate and potentially limit the installation of solar power plants based on the capacity constraints of its infrastructure.

Now, let's examine the situation from both economic and environmental perspectives from the PLN side. Potential reduced revenue, since TVS will install the solar power plant, can be derived by calculating the estimated energy generated by the solar power plant multiplied by the current tariff of PLN, which has the same amount as the annual savings for customers. Also, the reduced emission can be assumed to be the same as the annual reduced emission for customers. However, it is important to note that PLN has bigger emissions produced by conventional power plants in the beginning.

The total electricity production of PLN in 2023 amounted to 323,320.62 gigawatt hours (GWh)[52]. The installation of a solar power plant for 1 customer is estimated to generate 124,150 kWh. This amount is still relatively small when considering the overall energy mix. Therefore, the energy mix for PLN remains largely unchanged even after the installation of the solar power plant for the customer site.

It's important to note that the results of the calculation above are based on just 1 customer. Given the large number of PLN customers, the impact of 1 customer on both economic

Table 4.10: Economic Value and Environmental Impact for PLN

Metric	Value
Economic Value	
Annual Reduced Revenue (IDR)	- 2, 450, 336, 136
Profit from providing permit (IDR)	310,192,200
Cost of Advance Meter (IDR)	- 2,000,000
Environmental Impact	
Energy Mix	
Renewable Energy (%)	11%
Non-Renewable Energy (%)	89%
Annual Reduced Emissions (Kg CO2-eq)	1, 579, 188

Table 4.11: Economic Value and Environmental Impact for ICON+

Metric	Value
Economic Value	
Price of the Service (IDR)	14,000,000,000
Cost of Installation (IDR)	2,067,948,000
Cost of Material Procurement (IDR)	10,339,740,000
Cost of Permit (IDR)	310,192,200
Revenue (IDR)	1,282,119,800
No Direct Environmental Impact	

value and environmental aspects may not be significant. However, if we assume that 50 industry customers use solar power plants, the reduction in revenue would be quite substantial, and the environmental impact could be more noticeable. Hence, PLN has both advantages and disadvantages, but with this data, they can make more informed decisions about the trade-offs involved.

From an environmental perspective, PLN is obligated to adhere to government regulations aimed at reducing non-renewable energy sources for electricity in order to achieve net zero emissions. This requires PLN to transition its non-renewable energy-based assets into renewable energy, which entails investment. Through the solar power business scheme, PLN can benefit by incorporating renewable energy into its energy mix. Additionally, from an investment standpoint, PLN can reduce its initial investment in renewable energy since the investment is made by the customer. However, the strategy for increasing renewable energy should be approached separately; this assessment only provides an overview for PLN.

In the context of this business model, ICON+ holds a significant economic advantage due to its engagement in economic exchanges with PLN, customers, and EPC partners. While there is no direct environmental impact within this framework, ICON+ primarily operates as a digital business and has environmental impacts across its entire operations. However, for the purpose of this discussion, we will focus solely on the solar panel business. ICON+ generates revenue by offering solar power plant services. To calculate the profit, we need to consider the operational costs. However, there is limited available data on the operational cost of ICON+. In this instance, ICON+ received around IDR 13 billion for the service, but they still need to pay for the installation cost and material procurement. The amount will flow to the EPC partner and the manufacturer, with the cost of material procurement being the highest.

Table 4.12: Economic Value and Environmental Impact for Manufacturer

Metric	Value
Economic Value	
Revenue (IDR)	10,339,740,000
Gross Profit (IDR)	4, 509, 603, 600
Profit Margin(%)	43.59
Environmental Impact	
Produced Emissions (Kg CO2-eq)	36,456

Upon further evaluation of the customer, EPC partner, and manufacturer relationship, we can refer to Table 4.7, which presents the revenue for each party. The manufacturer receives IDR 10 billion, while the EPC Partner receives IDR 2 Billion. We can now proceed to analyse the manufacturer's gross profit and profit margin. Assuming that the Cost of Goods Sold (COGS) for a PV module is USD 0.37 per watt[75], equivalent to IDR 5,715 per module, we can calculate the gross profit and profit margin.

$$Total\ \ COGS = 5,715.82{\times}1,020,000 = \ \ IDR\ \ 5,830,136,400 \tag{4.25}$$

$$Gross\ \ Profit = 10,339,740,000{-}5,830,136,400 = \ \ IDR\ \ 4,509,603,600 \tag{4.26}$$

$$Profit\ \ Margin = (4,509,603,600/10,339,740,000){\times}100 = 43.59\% \tag{4.27}$$

We are seeking to determine the profitability for the EPC Partner. Assuming the installation cost per watt is USD 0,10, which equates to IDR 1,551 for labour benefit. The total cost of goods sold for a 1020 kwp solar panel installation amounts to IDR 1,581,020,000. The profitability analysis for the EPC partner will be presented below.

$$Total\ \ COGS = 1,551{\times}1,020,000 = \ \ IDR\ \ 1,581,020,000 \tag{4.28}$$

$$Gross\ \ Profit = 2,067,948,00 - 1,581,020,000 = 486,928,000 \tag{4.29}$$

$$Profit\ \ Margin = (486,928,000/2,067,948,00){\times}100 = 23.5\% \tag{4.30}$$

Next, we would like to evaluate the environmental impact of solar panel production. However, it's important to note that this study will not cover the environmental impact of installing solar panels for the EPC partner due to limited data availability. While the calculations in this study are based on existing research, it's essential to verify a more comprehensive evaluation by an expert. The greenhouse gas (GHG) emissions for monocrystalline panels are estimated to be 35.8 grams of CO2 per kilowatt-hour (kWh) of electricity. Additionally, provided below are the emissions produced by a 1020 kWp solar power plant.

$$Total\ \ Emissions = 1,020\ \ kWh{\times}35.8\ \ grams\ \ CO2/kWh = 36,456\ \ kg\ \ CO2e \tag{4.31}$$

From an economic standpoint, both manufacturers and EPC companies benefit from profit margins significantly higher than the average for solar power plants, which typically range from 20% to 25%[22, 32]. Environmentally, the CO2 emissions associated with the production of photovoltaic modules are roughly equivalent to the annual emissions of about eight average cars. However, a detailed assessment of emissions related to the installation process is lacking due to the need for more comprehensive data.

Table 4.13: Economic Value and Environmental Impact for EPC

Metric	Value
Economic Value	
Revenue (IDR)	2,067,948,000
Gross Profit (IDR)	486, 928, 000
Profit Margin(%)	23.5
Environmental Impact	
Produced Emissions (Kg CO2-eq)	unavailable data

The assessment results reveal that most stakeholders are realising reasonable profits. Customers are enjoying a high return on investment (ROI), indicating that their investments are indeed promising. Both manufacturers and EPC (Engineering, Procurement, and Construction) companies are securing substantial profit margins. ICON+ is notably benefiting from significant profits through management contracts and service offerings.

From an environmental perspective, this business model enhances the sustainability of customers' supply chains, making the investment both financially rewarding and environmentally responsible. However, it is important to note that customers inherit environmental impacts related to emissions from the production and installation of solar panels. Additionally, the overall environmental impact for manufacturers remains minimal, reflecting their commitment to sustainable business practices.

While PLN may face financial losses due to the installation of the power plant—since revenue from permits alone does not fully offset these losses—this factor is not the sole consideration. PLN operates with various business models and revenue streams. The contribution of the solar power plant business scheme to increasing PLN's renewable energy mix is relatively modest, given that most of PLN's power plants still rely on fossil fuels. Nevertheless, participating in the solar power sector aligns with green energy strategies and regulatory compliance, demonstrating a commitment to sustainability.

This case study illustrates the utility of the framework employed, but it is important to acknowledge that the assessment is not yet exhaustive. Limitations include restricted data availability, a lack of expert input, and the exclusion of other essential components, such as inverters and wiring. To achieve a more comprehensive evaluation, it is crucial to involve experts in both economics and environmental science to obtain accurate and relevant data.

5 TREATMENT VALIDATION

This chapter is part of the treatment validation and aims to answer the third research question regarding the model's effectiveness for practitioners.

5.1 Validation Criteria

The third research question aims to examine the impact of the designed framework on practitioners and assess its effectiveness. The validation process will focus on thoroughly evaluating the model's reproducibility, usability, and informativeness. By concentrating on these criteria, the validation process directly addresses how the framework assists practitioners in achieving a balance between economic growth and environmental stewardship. Expert opinion is the chosen method for validating these aspects.

- Reproducibility: The ability of different practitioners to achieve similar results when using the framework under comparable conditions[29]. Specifically, it will examine how accurately a practitioner can replicate results when following the framework.
- Usability: The ease with which practitioners can learn to use and implement the framework effectively[14]. This will assess their ability to implement the method in their current work and identify potential opportunities for its application.
- Informativeness: The extent to which the framework provides relevant and comprehensive information that supports decision-making. The validation will determine whether the model provides valuable analysis for business users, allowing them to understand the implications of balancing economic and environmental considerations.

5.2 Expert Opinion

The validation process involved the researcher arranging video conferences with the participants. During these sessions, the researcher provided an overview of the research. The explanation began with an overview of the currently available approaches and the new proposed method, including instructions on how to use it. Subsequently, the researcher presented a case study that used the new proposed method and explained the design choices for each step.

Following the initial presentation, semi-structured interviews were conducted to gather participants' opinions and feedback. Finally, the participants were asked to give their opinions on the reproducibility, usability, and informativeness of the method using a questionnaire that contains questions and measurement criteria as explained in section 5.2.2.

5.2.1 Validation Participants

Given that the method integrates both economic assessment and environmental impact perspectives, it is crucial to obtain feedback from both business development experts and environmental practitioners. This dual feedback approach enriches the evaluation, as each expert provides insights from their specific domain. Business development experts, with their deep understanding of economic valuation and market dynamics, can highlight the financial viability of the model. Environmental practitioners focusing on environmental impacts can assess the model's environmental implications. There are six participants validating the model. Three of them have a background in business development, while the other three have a background in environmental science.

1. Participant A is a Practitioner with 5 years of experience in Business and Product Development and has a background in Informatics Engineering.
2. Participant B is a renewable energy practitioner with experience in developing solar power plant business models.
3. Participant C is the Manager of business development specialised in electricity service.
4. Participant D has 7 years of experience as an environmental analyst at a power generation company.
5. Participant E has 7 years of experience in enterprise planning and a background in industrial engineering. Currently, E is a researcher delving into sustainable business.
6. Participant F has experience in risk management analysis and research about sustainability and environmental science.

5.2.2 Validation Questions and Measurement

To assess a designed method, a set of questions is created according to the validation criteria. The questions and measurement criteria for accurately quantifying the variables under study are listed in Table 5.1. Additionally, some open-ended questions are included to obtain feedback for refining the model. Below is the list of open-ended questions that were discussed during the validation process

1. What do you consider to be the main strengths of the framework?
2. What areas do you think need improvement?
3. Would you recommend this framework to other practitioners in your field? Why or why not?
4. Do you have any additional comments or suggestions for improving the framework?

5.3 Validation Result and Analysis

Based on the questionnaire results, the framework provides moderate to high assistance for practitioners in making informed decisions to balance economic growth with environmental stewardship. Although there are some challenges related to ease of implementation, most practitioners find the framework valuable for identifying opportunities, supporting

Table 5.1: List of Questions Derived from the Validation Criteria

Question	Measurement Criteria
Reproducibility	
Q1:How accurately are you able to replicate results when following the framework?	1. It is hard to produce a similar result 2. Accurate replication of results 3. Accurate replication and clear guidance for achieving similar outcomes
Usability	
Q2:How easy was it for you to learn and use the framework based on the presentation?	1. I find it hard to understand 2. Understandable and easy to follow 3. Understandable, easy to follow, and seems easy to implement
Q3:How straightforward was it to implement the framework in your current work?	1. Hard to implement 2. Quite straightforward 3. Straightforward, seamless integration, and practical for daily use
Q4:Can you identify any potential opportunities for applying this framework in your practice?	1. I do not see any potential to apply this in practice 2. Potential opportunities and clear applications in current projects 3. Potential opportunities, clear applications, and added value to existing processes
Informativeness	
Q5:Does the result of the framework provide comprehensive and relevant information that supports your decision-making process?	1. The information is not relevant 2. Provides relevant information 3. Provides relevant, comprehensive information, and aids in informed decision-making
Q6:How valuable is the analysis provided by the framework for balancing economic and environmental considerations?	1. Does not help the analysis 2. Valuable and actionable analysis 3. Valuable, actionable analysis and enhances understanding of implications

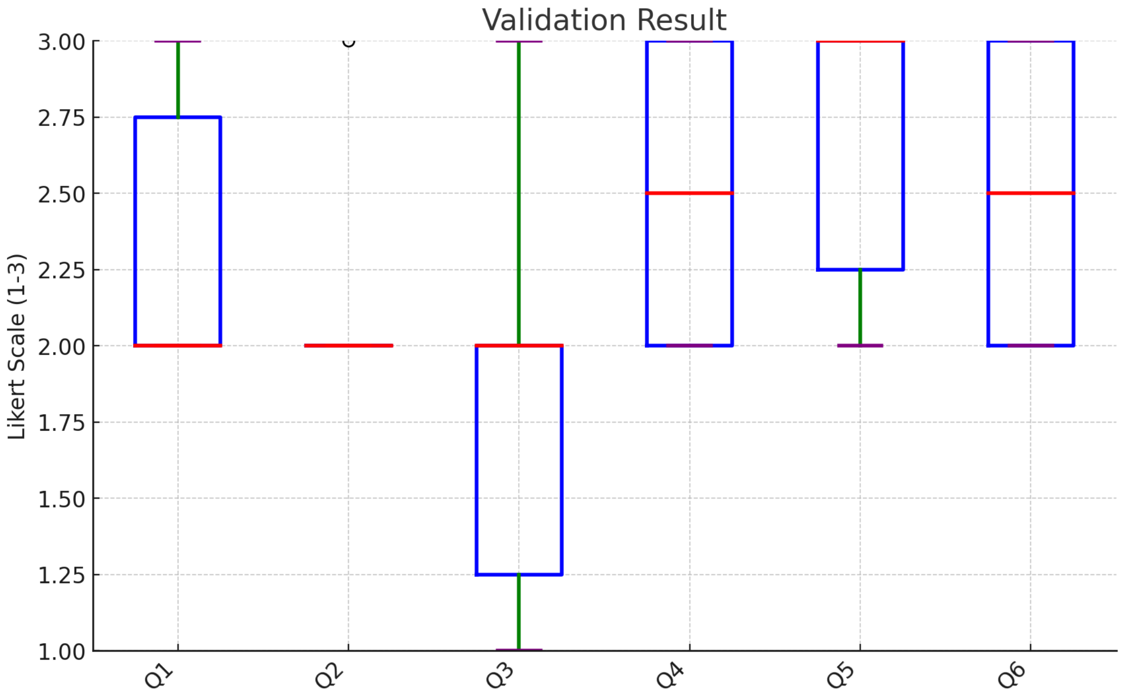


Figure 5.1: Validation Result

decision-making, and balancing economic and environmental considerations. The mixed but generally positive ratings suggest that the framework has potential but could benefit from further refinement and support to improve ease of use and implementation. The summary of the validation results is depicted in Figure 5.1, and each validation criterion will be elaborated upon below.

5.3.1 Reproducibility

When asked about the possibility of achieving a comparable outcome using a similar approach in a similar scenario, the respondents affirmed their capability to do so. It is foreseeable that a consistent result could be achieved as long as the scope definition remains unchanged, given the dependency of e3value on the stakeholder. The findings also suggest a moderate level of confidence in the framework's ability to produce replicable results, with some practitioners finding it more reliable than others.

The box plot displayed in Figure 5.1 represents the distribution of responses to question Q1 concerning reproducibility. The data shows that the majority of responses cluster between the values of 2 and 3, suggesting that respondents are capable of consistently reproducing the same results. This implies that most participants believe that the framework offers clear guidance, enabling them to achieve consistent outcomes.

5.3.2 Usability

Upon reviewing the presentation, the audience generally found it to be comprehensible. However, the box plot analysis indicates varied levels of ease regarding the framework's usability. The majority of respondents found it moderately easy to learn and use the framework, reflecting a generally positive reception. However, the variability in responses suggests that while the presentation was clear, some practitioners might still find practical

implementation challenging.
For usability, represented by questions Q2, Q3, and Q4, the box plots reveal nuanced insights:

- Q2 (Ease of Learning): The responses are tightly clustered around the median, indicating that most participants found the framework easy to learn from the presentation. The small interquartile range suggests minimal variation in perception, meaning the presentation was effective in conveying the core concepts clearly.
- Q3 (Ease of Implementation): This question received the most diverse responses, with the minimum value dropping to 1, indicating that some participants found implementation quite challenging. The wide spread of the data suggests mixed experiences, with some practitioners finding the framework straightforward to implement, while others struggled, possibly due to the complexity of applying the framework in real-world scenarios.
- Q4 (Identifying Opportunities): Responses to this question showed a trend toward higher ratings, with the median closer to 3. This suggests that while participants see potential in applying the framework, their confidence varies. The wider interquartile range compared to Q2 indicates that while the majority see clear opportunities, there is a significant portion of respondents who might need further clarity or support in recognising these opportunities.

The usability of the framework is generally well-regarded, but the responses highlight that while learning the framework is straightforward, implementing it and recognising its opportunities can present challenges for some practitioners. Tailoring additional support or guidance to address these implementation concerns could help enhance overall usability.

5.3.3 Informativeness

The participants' feedback on the framework's informativeness, specifically assessed in Q5, was generally positive. The box plot for Q5 shows that the majority of responses are clustered towards the higher end of the scale, with the median response at 3. This indicates that most participants found the framework not only relevant but also comprehensive and useful for making informed decisions. The small spread in the data suggests that there was strong agreement among respondents, with few perceiving the information as irrelevant. This consistent clustering towards the higher ratings demonstrates the framework's effectiveness in providing the necessary insights that practitioners need for decision-making.
For Q6, which evaluates the framework's value in balancing economic and environmental considerations, the box plot shows that responses are somewhat more varied but still positive overall. The median response is 3, indicating that many participants found the framework both valuable and capable of enhancing their understanding of the implications of their decisions. The data distribution suggests that while some participants see the framework as simply providing valuable and actionable analysis, others recognise its deeper impact on their comprehension of complex trade-offs between economic and environmental factors.
The box plot analysis for both Q5 and Q6 reflects a generally positive reception of the framework. Most participants regard the framework as providing relevant, comprehensive information that supports informed decision-making (Q5) and as a valuable tool for balancing complex considerations in their work (Q6). The strong clustering of responses

towards the higher end of the scales reinforces the framework's perceived utility and effectiveness.

5.3.4 Discussion and Feedback

During the session, various discussions were initiated. Participants provided feedback on the strength of the proposed method, noting its innovative approach to considering both economic and environmental factors within the business model. They emphasised how the framework aids in identifying accountable stakeholders, developing action plans, assessing value, analysing product lifecycles, and evaluating post-implementation impacts. They also emphasised that clear and comprehensive guidelines help them map the business model that involves many stakeholders.

The participants' opinions emphasise the significant impact of the framework on practitioners. This is notable because it considers the environmental impact, which is uncommon in business models. The framework is comprehensive and easy to understand and evidently affects not only the economic aspect but also the environmental side. Given the complexity of the business ecosystem, this framework would simplify the identification of the scope for all involved stakeholders. It is very beneficial, providing a comprehensive view that can guide better decision-making and ensure sustainable outcomes.

Furthermore, they also provided feedback for improving the framework, which included several detailed suggestions. One respondent noted that the data collection phase could be enhanced for more accurate results, especially for environmental analysis. Additionally, it was suggested that using existing research for the LCA could be a wise choice, but attention should be paid to the scope of the previous research. Providing a clearer description of the boundaries and units for the LCA system and the assumptions used was also recommended. It was suggested that the graphics and diagrams be enhanced to provide more detail and clarity in explaining the framework. Moreover, it was recommended that a more easily understandable chart for the high-level economic value structure be included and that the time period be incorporated into the framework, as different periods can yield varying results.

5.3.5 Alignment with The Stakeholders and Their Goals

In Chapter 3, an exploration of potential stakeholders who will be interested in and benefit from the integrated approach is undertaken. The chapter also outlines the specific goals of each stakeholder involved. While six stakeholders are defined in the chapter, it is crucial to acknowledge that not all were included in the validation process, which consequently narrows the scope of the validation results. The validation was carried out with the active involvement of a business development officer and a corporate sustainability officer. Notably, the participant pool was evenly split, with half representing the business development area and the other half consisting of environmental specialists serving as corporate sustainability officers.

The primary objective of the Business Development Officer is to drive the company's growth and expansion while ensuring that these efforts align with environmentally sustainable practices and profitability. Validation results indicate that this framework has significant potential to support these objectives. One key responsibility of the Business Development Officer is to explore opportunities for the company to generate profit with minimal environmental impact. By leveraging this method, they can test various scenarios to assess how different approaches influence both profitability and environmental sustainability. The use of visualisation tools allows for clear illustration and communication of complex information and facilitates strategic planning. One participant noted that the framework enables a more organised explanation of stakeholder relationships, which is crucial for strategic business development.

The validation results illustrate that the framework offers pertinent and comprehensive information that is essential for decision-making, particularly with regard to informativeness. It is also viewed as a valuable tool for balancing economic value with environmental impact, further emphasising its usefulness in supporting the objectives of a business development officer. For a Business Development Officer, having access to accurate and detailed information is imperative as it allows for the evaluation of various strategies and the prediction of potential outcomes. This high level of informativeness ensures that decisions are grounded in solid evidence rather than assumptions, thereby reducing the risks associated with strategic initiatives.

The primary aim of the Sustainability Officer is to incorporate sustainability into the corporate strategy and operations by showcasing the business case for sustainability, highlighting both environmental and economic benefits. The validation results indicate that this framework effectively supports this objective by providing a comprehensive analysis that integrates economic and environmental considerations. This approach ensures that sustainability is regarded as a foundational element of the corporate strategy, rather than an afterthought, thus empowering the Sustainability Officer to present a compelling business case for sustainability within the company.

Additionally, one participant pointed out that the hypothesis about higher operational costs when environmental assessments are conducted at a later stage of business development is likely accurate. Implementing this integrated method early on could considerably contribute to achieving sustainability goals and potentially reduce costs associated with delayed environmental assessments. This proactive approach emphasises the framework's potential value in aligning sustainability with economic objectives, making it a valuable tool for the Sustainability Officer's mission.

6 CONCLUSION

6.1 Reflection on Research Question

In this research, we sought to address the central question:
How can a business value model be developed and refined to assess economic value and environmental impact based on the existing method(s) to assist businesses in making informed decisions that effectively balance economic growth with environmental stewardship?

This question aims to explore the development of a new method to evaluate economic and environmental impacts within a business model, highlighting the trade-offs between these aspects. By doing so, it enables decision-makers to make more informed choices that consider both economic and environmental dimensions.
A sub-research question has been formulated to address the primary research inquiry. Subsequent sections of this report delve into the findings pertaining to the sub-research question. This part will provide a reflection on each sub-research question.

SQ1 What is the state of the art in environmental impacts assessment methodologies and business network models?

The research explores the e3value tool, which is suitable for evaluating business network models and LCA, which is a widely accepted method for assessing environmental impact. Two methods that assess economic and environmental impact are also found: BM-LCA and LCA-NPV, which build upon LCA. BM-LCA incorporates the business model into the LCA methodology, with an emphasis on goal and scope definition. In contrast, the proposed method integrates economic and environmental metrics and offers modelling and visualisation tools from e3value, incorporating environmental aspects such as life cycle stage and impact exchange.

Furthermore, the study compared the proposed method with LCA-NPV, which comprehensively assesses environmental impact and quantifies a business model's NPV. While LCA-NPV is suitable for comparing two business models, the proposed method is more appropriate for defining a business ecosystem and offers flexibility by considering additional economic and environmental metrics beyond NPV.

SQ2 How can the business network model and environmental impact be combined to assess both aspects in a unified framework?

The proposed method detailed in Chapter 4 is the result of an iterative process involving experimentation with two different methods and analysis of their similarities and differences. The latest iteration, depicted in Figure 4.5, presents a refined approach that includes key elements and step-by-step guidelines. Its feasibility has been demonstrated through its application to a real-world case study about the solar power plant business ecosystem.

When applying the method to this specific case, we can identify key elements that need definition, along with presenting the model of the business ecosystem and an overview of the economic value and environmental impact. This overview enables us to pinpoint the necessary data for the assessment process. The assessment step also provides information on economic value and environmental impact, demonstrating how the method can effectively assess economic value and environmental impact. This showcases its practical insights and validates its usefulness for informed decision-making in this specific context.

The method has been validated within a solar power plant business ecosystem, but its structured approach and flexibility indicate that it can be applied beyond this specific scenario. The key elements and step-by-step guidelines can be tailored to suit different business models and ecosystems. Balancing economic growth and environmental stewardship is a universal challenge across industries, making this method pertinent for a wide range of applications.

SQ3 To what extent does the designed framework assist practitioners in making informed decisions to balance economic growth with environmental stewardship?

The proposed method was presented to six participants with expertise in business and product development, as well as environmental science and sustainability. The validation process aimed to measure the method's effectiveness for practitioners using three criteria: reproducibility, usability, and informativeness.

- Reproducibility: The results were moderate. This is likely due to the method being relatively new and the variability in participants' interpretations and applications.
- Usability: The usability results were also moderate, indicating that while the method shows promise, it requires further refinement to enhance its ease of use.
- Informativeness: The informativeness was rated slightly higher, suggesting that participants found the method helpful and relevant for decision-making. However, it is important to note that participants were already familiar with the case study, which may have influenced their perception of the method's usefulness.

Overall, considering that this was the first validation of the new method, the results are promising but indicate the need for further refinement and research to improve its reproducibility and usability.

6.2 Limitation

In conducting the research, it is crucial to recognise the constraints that were encountered:

1. Specific Application: In a specific instance, a method was demonstrated. However, its applicability across various industries and business contexts has not undergone comprehensive testing, potentially limiting its generalisability.

2. Specific Knowledge Requirement: The LCA component of the method requires specific expertise. Gathering and analysing LCA data necessitates a level of specialisation that may not be available in all business contexts.

3. Limited Data for Environmental Aspects: The data gathered for the case study, especially for the environmental aspect, was limited. In this case, the environmental data was sourced from previous research, which, although still relevant, may not fully capture current conditions. Environmental impact can vary significantly based on different parameters, and for cases where environmental data cannot be easily acquired, it is necessary to involve experts from the related field.

4. Stakeholder Involvement: The validation process was constrained by limited diversity in the types of stakeholders involved. Because the method affects various stakeholders across different roles and business functions, this limitation may have led to a narrower range of perspectives and feedback.

5. Interdisciplinary Collaboration: In order for the method to be successfully implemented, it is crucial for multiple experts to collaborate closely. This includes economic or business specialists as well as environmental specialists. This interdisciplinary approach is essential for conducting precise assessments of both economic and environmental impacts. Furthermore, the involvement of all stakeholders in the analysis is imperative, as limited engagement from any stakeholder could lead to incomplete assessments and less-than-optimal outcomes.

6.3 Recommendation on Future Research

To address the limitations and further improve the proposed method, the following recommendations for future research are suggested:

1. To validate the method, it is essential to conduct case studies across diverse industries to assess its adaptability and identify industry-specific challenges, ensuring its robustness across various applications.

2. Developing specialised tools to efficiently gather and organise data, such as tools capable of retrieving environmental data from previous research or LCA databases, will streamline the data collection process and ensure comprehensive environmental assessments.

3. Enhancing the method with tools specifically designed to quantify economic and environmental data will improve its precision and reliability by facilitating accurate measurement and integration of various metrics.

4. Enhance the ontology of e3value to include the capability to visualise environmental impact, life cycle stage, and environmental flow.

5. Investigate how this method can be used to strengthen business cases by providing detailed insights into economic and environmental impacts. This exploration will help businesses make more informed decisions and create stronger justifications for their strategies.

6. Future research should focus on strategies to facilitate collaboration between economic or business specialists and environmental specialists, ensuring a holistic approach to assessments.

6.4 Summary

The objective of this research was to develop a framework for assessing the economic value and environmental impact to support decision-making within business ecosystems. The proposed method integrates elements from e3value and LCA, offering a groundbreaking approach that combines economic and environmental metrics with modelling and visualisation tools.

The methodology employed was design science, which enabled the investigation of the problem, the design of the solution, and the validation of the proposed method. Through an iterative process and its application to a real-world case study in the solar power plant business ecosystem, the method demonstrated its feasibility and potential effectiveness. Validation with experienced practitioners revealed moderate scores in reproducibility and usability but higher scores in informativeness, indicating the method's relevance and practicality.

This research makes a valuable contribution by constructing a method that connects economic value assessment with environmental impact analysis. By integrating e3value's business modelling capabilities with LCA's environmental assessment, a more holistic approach to evaluating business ecosystems is achieved. This method offers a structured way to visualise and quantify the trade-offs between economic growth and environmental stewardship, which is crucial for promoting sustainable business practices.

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A FIRST APPENDIX

Query Formulation for two scientific databases (Scopus and Web of Science) :

1. Scopus (`https://www.scopus.com`)
   - Q1
     (TITLE-ABS-KEY("sustainability impacts assessment" OR "environmental impact analysis" OR "eco-efficiency" OR "Life Cycle Assessment" OR "LCA" OR "environmental footprint" OR "sustainability measurement tools") AND TITLE-ABS-KEY("economic value" OR "profitability") AND PUBYEAR AFT 2018 AND PUBYEAR BEF 2025 AND (DOCTYPE(ar) OR DOCTYPE(cp) OR DOCTYPE(re)) AND (SUBJAREA(BUSI) OR SUBJAREA(COMP)) AND NOT SUBJAREA(BIOL)) AND LANGUAGE(english)
   - Q2
     (TITLE-ABS-KEY ("business network" OR "economic value" OR "profitability") AND TITLE-ABS-KEY ("e3value" OR "value modeling")) AND (PUBYEAR > 2010) AND (LIMIT-TO (OA , "all")) AND (LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "BUSI")) AND (LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))
   - Q3
     (TITLE-ABS-KEY ("environmental impact assessment" OR "life cycle assessment") AND TITLE-ABS-KEY ("value network" OR "value modelling" OR "e3value" OR "business model" OR "business network model") AND TITLE-ABS-KEY (integration OR interrelation OR combination OR framework OR approach)) AND (LIMIT-TO (OA , "all")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp")) AND (LIMIT-TO (SUBJAREA , "busi") OR LIMIT-TO (SUBJAREA , "comp") OR LIMIT-TO (SUBJAREA , "econ")) AND (LIMIT-TO (LANGUAGE , "english"))
2. Web of Science (`https://webofscience.com`)
   - Q1
     TS=("sustainability impacts assessment" OR "environmental impact analysis" OR "eco-efficiency" OR "Life Cycle Assessment" OR "LCA" OR "environmental footprint" OR "sustainability measurement tools") AND TS=("economic value" OR "profitability") AND PY=(2019-2024) AND (DT=(article OR conference paper OR review)) AND (SU=(Business and Economics OR Computer Science) NOT SU=(Biology)) AND LA=(English)

Table A.1: Query Search Keyword

Environmental Impacts Assessment	**Business Network Modelling**	**Integration**
Environmental impact analysis	Business network	Interrelation
Environmental impact performance	Economic value	Combination
LCA	Profitability	Framework
Life Cycle Assessment	E3value	Approach

Table A.2: Queries for each sub-research question

sub-RQ	**Query ID**	**Topic**
sub-RQ1	Q1	Environmental Impacts Assessment, Business Network
sub-RQ2	Q2	Business Network Modelling, Economic Value, Environment Performance
sub-RQ3	Q2	Interrelation Between Business Network Model and Sustainability Assessment Method

- Q2
  TS=(”business network” OR ”economic value” OR ”profitability”) AND TS=(”e3value” OR ”value modelling”) AND PY=(2011-2024)
- Q3
  (TS=(”environmental impact assessment” OR ”life cycle assessment”) AND TS=(”value network” OR ”value modelling” OR ”e3value” OR ”business model” OR ”business network model”) AND TS=(integration OR interrelation OR combination OR framework OR approach)) AND (DO=(article OR conference proceedings)) AND (SU=Business and Economics OR SU=Computer Science OR SU=Economics) AND (LA=English) AND OA=(ALL)

Inclusion Criteria

1. Inclusion of literature published in the last ten years
2. Inclusion of literature conducted in English
3. Inclusion of study within the domain of Computer Science, Business Management and Accounting.

Exclusion Criteria

1. Exclusion of duplicate literature across database
2. Exclusion of studies that are either unavailable or incomplete
3. Irrelevant literature based on its abstract to this study’s defined research questions

Selection Process

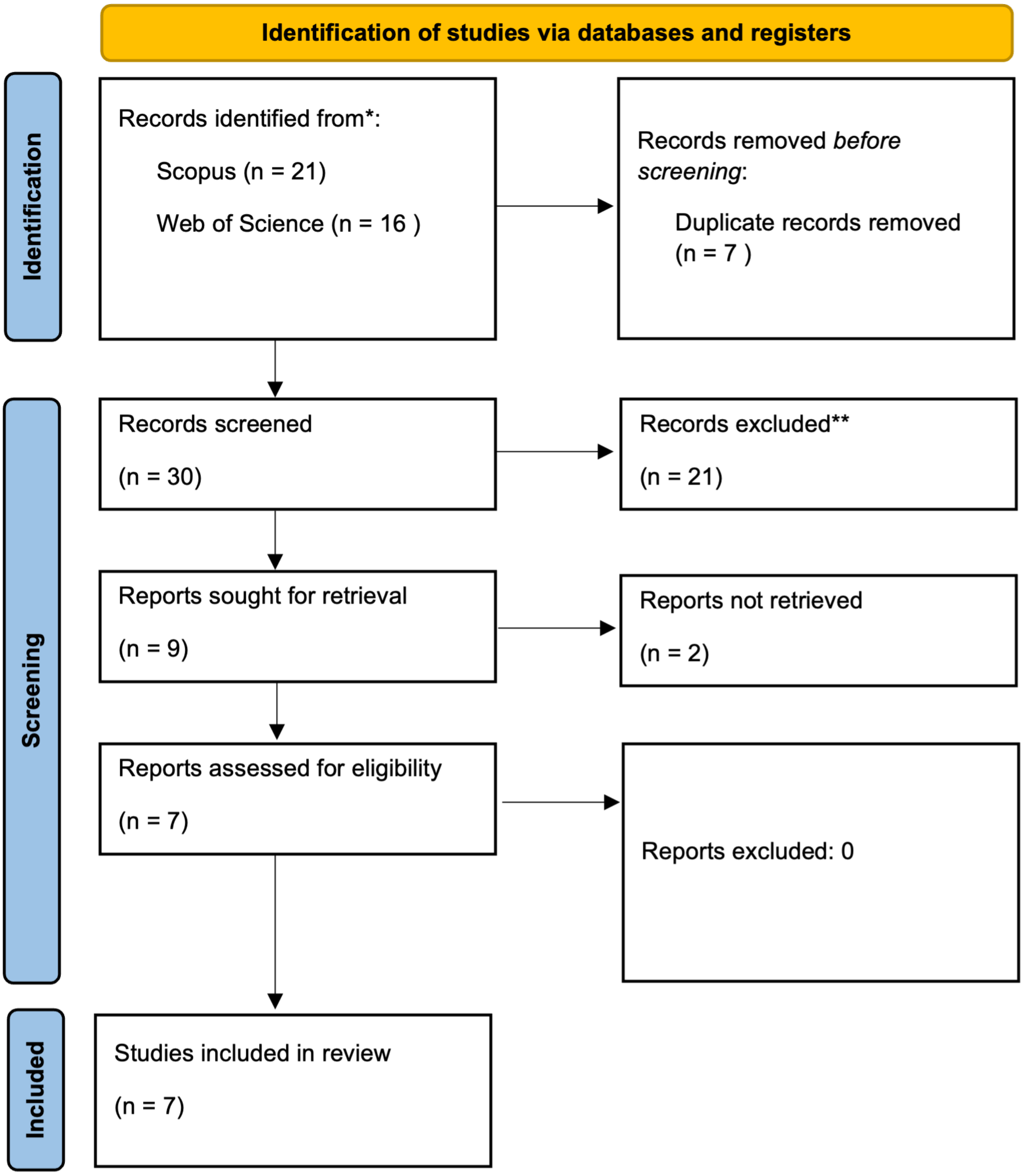

Figure A.1: Selection process of Sub-research Question 1

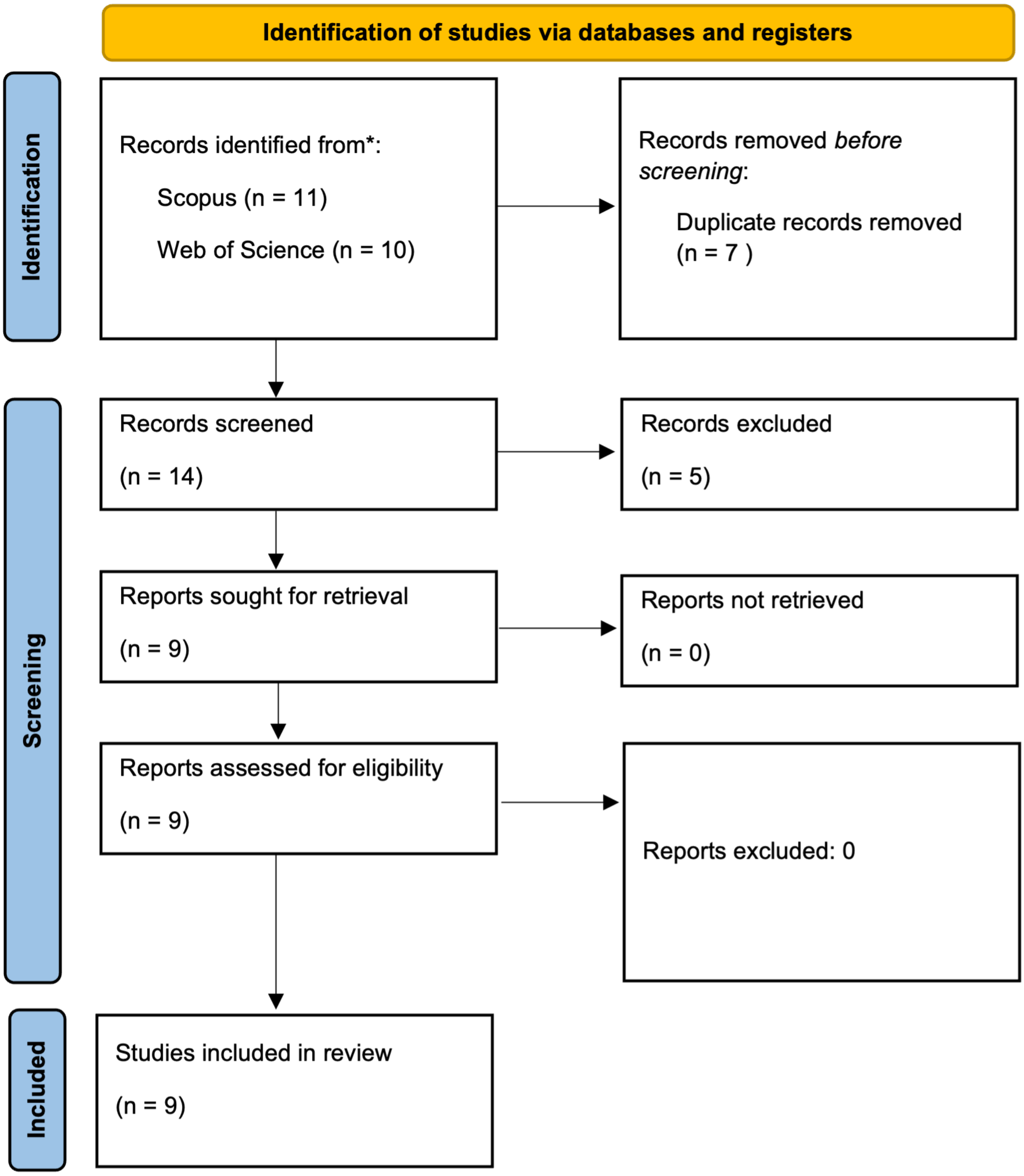

Figure A.2: Selection process of Sub-research Question 2

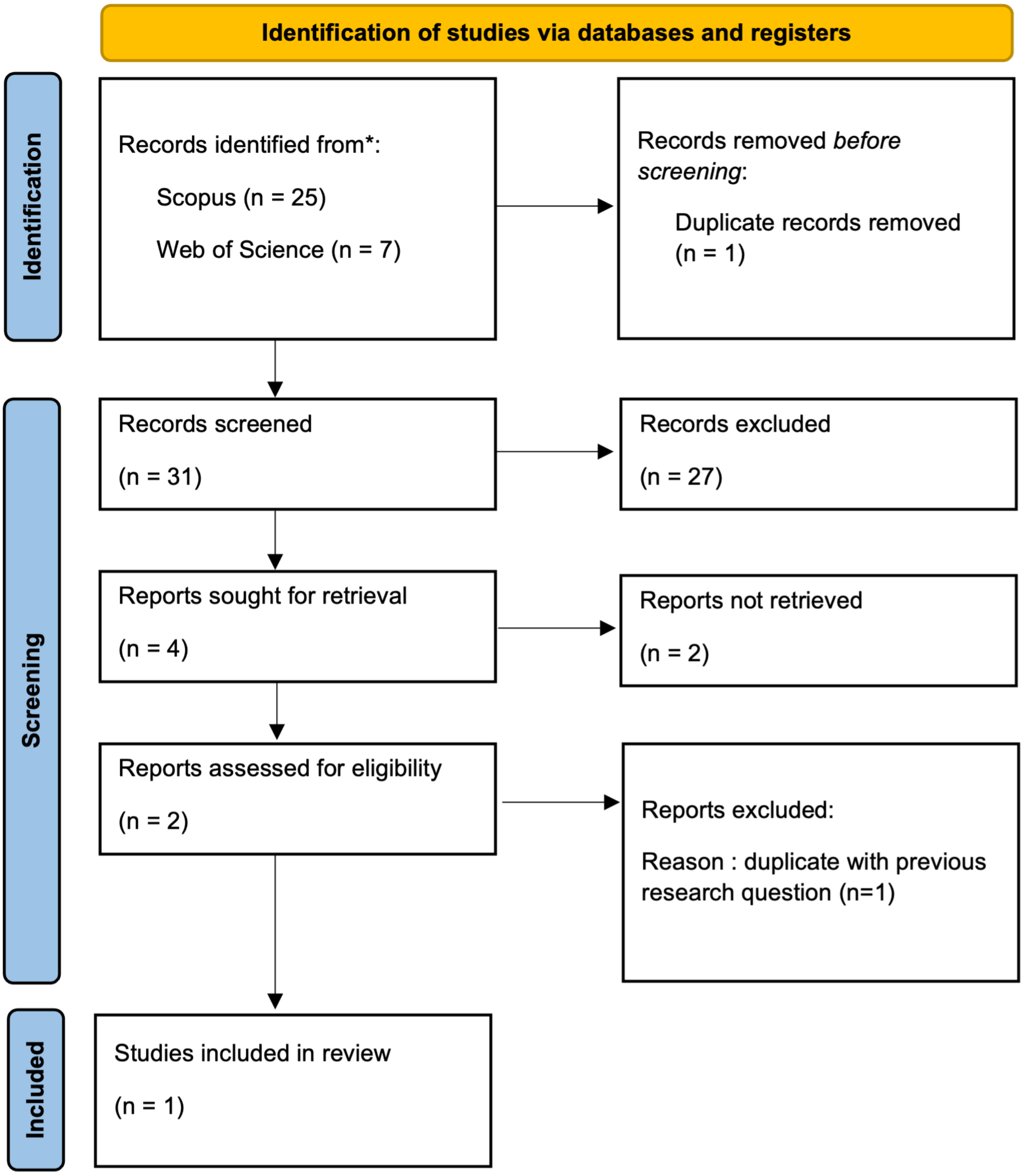

Figure A.3: Selection process of Sub-research Question 3