Developing Advanced Approaches to Deliver Value on Construction Projects: Integrating Social Dynamics, Digital Modelling Techniques, and Lean Concepts

by

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ABSTRACT

Construction projects are complex endeavors that involve multiple stakeholders, challenging processes, and diverse objectives. The effective management and alignment of project value propositions are crucial for ensuring successful outcomes and satisfying the needs and expectations of stakeholders. Value Management practices have offered ways to support the identification and generation of project value. However, conflicting and unclear requirements among stakeholders hinder a shared understanding of project value leading to issues such as varied work practices, rework, low productivity, and increased costs. Moreover, the lack of reliable tools and methods to track value attainment during design development undermines the effectiveness of value management workshops usually conducted in early phases. Additionally, insufficient attention is given to studying the impact of social dynamics on the delivery of value on projects. Accordingly, this research aims to improve project value delivery and value management practices by rethinking value identification and planning methods, and by proposing a digital simulation tool with metrics to track and control value throughout project phases. Specifically, the study recognizes the significance of social dynamics such as interactions, relationships, and behaviors of individuals and groups, in shaping project outcomes. The research recognizes the transformative potential of digital methods and lean principles in enhancing value management practices. Accordingly, three major modules are outlined: (1) mapping factors influencing value delivery, recommending value identification strategies, and proposing a simple-warning dashboard for detecting value conflicts, (2) developing a socio-technical framework to track value attainment and evaluate design communication and team structures using social network analysis and lean practices, and (3) deploying simulation as a value management tool using agent-based modelling techniques to

monitor value alignment and fulfillment throughout the project design. In addition to the mentioned modules, a portion of this research was dedicated to investigating architecture and engineering education with respect to teaching value and proposing essential practices to overcome the identified shortcomings. The overall objective of this research is to create value in the built environment for everyone by advancing both industry practices and educational systems toward a more human-centric design and management. By prioritizing human and social capital, while ensuring alignment with the diverse needs and requirements of all stakeholders, the identification, tracking, and management of social, cultural, and environmental value using digital tools contribute to equitable satisfaction and well-being of all entities engaged in construction projects.

PREFACE

This thesis is an original work by Salam Ghazi Khalife and follows the format of a paper-based dissertation. Various chapters included in this work have been organized in journal article format and are under review in peer-reviewed journals. A total of three journal articles and six conference papers have been published or submitted for publication, all of which bear a direct relation to the thesis topic and are integral components of it. The inclusion of the different papers is explained hereafter.

A version of **Chapter 2** has been published in two conference papers as (A) **Khalife, S.**, Emadi, S., Wilner, D. & Hamzeh, F. (2022) "Developing Project Value Attributes: A Proposed Process for Value Delivery on Construction Projects" *Proceedings of the 30th Annual Conference of the International Group for Lean Construction (IGLC)*, Edmonton, Canada, July 2022; The paper is reprinted with the permission of the IGLC committee and is accessible online at: https://doi.org/10.24928/2022/0202; and (B) **Khalife, S.** and Hamzeh, F. (2022) "Developing a Value Dashboard for Tracking Value Alignment on Construction Projects During Design" *In Construction Research Congress*. Arlington, Virginia, March 2022; The paper is reprinted with the permission of the American Society of Civil Engineers and is accessible online at: https://ascelibrary.org/doi/abs/10.1061/9780784483978.053. In the first paper, Khalife was the lead investigator and was responsible for concept formation, process development, and paper composition and writing. Emadi was an exchange PhD student from Universitat Politecnica de Catalunya and conducted literature review; Wilner was the project manager on one of the case studies used in this paper and assisted in validating the ideas in the paper; Dr. Hamzeh was the

supervisor and contributed to research guidance and supervision. In the second paper, Khalife was responsible for concept formation, dashboard development and validation. Dr. Hamzeh was the supervisory authority and contributed to concept formation and guidance.

A version of **Chapter 3** was accepted for publication as **Khalife, S.,** Pourrahimian, E., Didluck, T., and Hamzeh, F. (2023) "Demystifying the dynamic link between project value and design team networks: a socio-technical lean management framework". *Journal of Architectural Engineering and Design Management*. Khalife was the lead investigator and was responsible for concept formation, framework development, case study involvement and analysis, and manuscript composition. Pourrahimian was responsible for the fuzzy analysis and identifying correlations. Didluck was the project manager on the project used in this research and contributed with validating the analysis and sharing insights. Dr. Hamzeh had supervisory role and contributed to reviewing the work.

A version of **Chapter 4** was submitted for publication as **Khalife, S.,** Shehab, L., and Hamzeh, F. (2023) "Employing simulation to assess value alignment and fulfillment within construction project settings and team dynamics" in Automation in Construction Journal. Khalife was the lead investigator on the study and was responsible for conceptual model formation, mathematical model formation, case study application, and paper compositions and writing. Shehab was responsible for developing the computational model. Dr. Hamzeh was the supervisory authority and contributed to concept formation and reviewing of the manuscript.

A version of **Chapter 5** was submitted for publication and is under review as **Khalife, S.,** Rybkowski, Z., and Hamzeh, F. (2023) "Advancing Engineering and Architecture Education for

Value Delivery" *Journal of Civil Engineering Education*. Khalife was responsible for concept formation, conducting the survey and the statistical analysis, and developing the framework. Dr. Rybkowski was involved in conceptualization and manuscript review. Dr. Hamzeh is the supervisory authority and was involved in project administration and manuscript review.

The research conducted under this dissertation received two research ethics approval from the University of Alberta Research Ethics Board. The first application was received for the research conducted in Chapter 5 under the study ID Pro00104344 titled: "Evaluating the Value Concept within the AEC Curricula" (Date: October 2020) . The second application was received for the research conducted in Chapters 2, 3 and 4 under the study ID Pro00114576 titled: "Modelling and investigating value communication patterns within the social networks of different project settings" (Date: October 2021).

Other publications in reference to this work:

Khalife, S. and Hamzeh, F. (2019) "A Framework for Understanding the Dynamic Nature of Value in Design and Construction" In: *Proc. 27th Annual Conference of the International Group for Lean Construction (IGLC).* Dublin, Ireland, 3-5 Jul 2019. pp 617-628.

Khalife, S. and Hamzeh, F. (2020) "Managing Perceived Project Value: An Exploratory Study into the Designer's Role within the C-K Theory" ASCE Construction Research Congress. Arizona, USA, March 2020.

Khalife, S. and Hamzeh, F. (2020) “Measuring Project Value: A Review of Current Practices and Relation to Project Success” 28th Annual Conference of the International Group for Lean Construction (IGLC). Berkeley, California, USA, 6-10 July 2020. pp 37-48.

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To my family, Mama, Sara, Ali, and Fawzi, may God continue to bless our unbreakable bond.

To my Dad… may your soul rest in peace. Fate took you away in the middle of this journey when I needed you the most. You strived to witness this day, the day I complete my degree and we celebrate this major milestone in my life; you wanted to tell me again and again how proud you are of me. I imagined this moment since day one I started my PhD. You are not here today, but you are watching over, and your words were my push during difficult times. I am here now, and it is all because of you. Your social butterfly has made it. May we celebrate it someday somewhere. This work is dedicated to you.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AEC	Architecture, Engineering, and Construction
AHP	Analytical Hierarchy Process
BIM	Building Information Modelling
CBA	Choosing By Advantages
CEM	Construction Engineering and Management
CMR	Construction Manager at Risk
IPD	Integrated project Delivery
KPI	Key Performance Indicator
PMBOK Guide	A Guide to the Project Management Body of Knowledge
VA	Value Attribute
VAL	Value Attributes List
VM	Value Management

Chapter 1: Introduction

To understand the value in projects is to understand how to be a force for good as contributors in the built environment.

1.1 BACKGROUND

The construction industry is experiencing a shift from simply delivering *projects* to focusing on delivering *value*. This shift delves into project performance beyond the traditional iron triangle of cost-time-quality, embracing a focus on value performance in the new production era (Tezel et al., 2018). Studies have indicated that a project may be considered a failure, despite meeting the criteria of timely delivery, budget adherence, and meeting the specified quality (Pargar & Kujala, 2021). Accordingly, project success is now evaluated based on its ability to fulfil the realized value of multiple stakeholders, namely the client, designers, builders, public agencies, operators, end-users, and surrounding communities, to ultimately achieve their satisfaction (Chan & Chan, 2004). Project Value thus reflects stakeholders' needs, requirements, desires, and interests in terms of functionality, durability, sustainability, aesthetics, etc. (Emmitt et al., 2004).

Nevertheless, the architecture, engineering, and construction industry (AEC) is overburdened with projects that are often completed without the satisfaction of the different stakeholders. The major problem lies in stakeholders' conflicting requirements, thus formulating different understanding of what constitutes project value (Haddadi et al., 2016). The poor integration of stakeholders' needs and interests has major implications such as differences in work practices, rework, deficient productivity, and diminished work performance. This is subsequently leading to unexpected cost overruns and disputes. Additionally, the route to reaching a common understanding of project value and translating it into a satisfactory project is plagued with various issues, including inadequate coordination, ineffective traditional management practices, lack of

metrics assessing compliance with value requirements, and the list continues. Therefore, design and construction companies are seeking improved efficient practices and tools to resolve these issues, establish the required conditions for them to collaborate together, and increase project value delivery (Tillmann et al., 2013). The AEC industry is progressively transitioning towards a more integrated and efficient project delivery approaches, aiming to create value through enhanced collaboration. This shift is being driven by the adoption of Lean principles, such as target value design and set-based design, and the utilization of digital technologies like Building Information Modelling (BIM), which promote the coordination needed on construction projects (Park et al., 2017; Tillmann et al., 2013).

Moreover, Value Management (VM) stands as a crucial approach aimed at generating and capturing client values (Kelly, 2003). The notion of value management originated in the manufacturing industry through the value methodology, and it was recognized in construction over 50 years ago (Kelly et al., 2004). Since then, the world has witnessed numerous value management approaches under different terms and institutions, namely: Value Methodology under SAVE International – USA, the Institute of Value Management – Australia, Value for Europe, Value Management Model – Japan, Hong Kong Institute of Value management, Value Management and Functional Analysis – UK, among others. Nonetheless, research investigating the early application of these methodologies found that the motive for using these approaches was cost reduction (Jay & Bowen, 2015). Additionally, numerous researchers and industry leaders are increasingly advocating for early co-creation of value in engineering and construction projects with the diverse set of stakeholders, and they are calling for more research on the subject (Barima, 2010; Candel et al., 2021; Institution of Civil Engineers, 2021; Liu et al., 2019; Winter & Szczepanek, 2008). An article discussing construction engineering and management (CEM) research for the next 50 years

emphasized the importance of maximizing economic, environmental, and societal value of the built environment and broaden the methods and tools to capture them (Levitt, 2007). Accordingly, this research focuses on developing advanced tools to facilitate the investigation of value management by focusing on different influential factors on projects, thereby addressing a notable gap in existing certifications and workshop methodologies.

Since its inception, the concept of value has sparked debates and has become one of the most excessively used yet misunderstood ideas in social sciences domains, particularly in the management literature (Salem Khalifa, 2004). Various definitions are suggested in the construction management literature. The most common expression for value according to (Kelly, 2007) was found to be in its relationship with function and cost (expressed mathematically as value equals function over cost). However, in the same study, Kelly (2007) argumentatively provided an alternative to this relationship which should go beyond function and cost. He argued that value is explained in the client value system which is multifaceted and is only defined on a project-by-project basis and in reference to the specific project's stakeholders. A study investigating 19 years of publications that explore this concept, summarized the common aspects that now define value. The authors indicated that value is defined as the client's needs, where the client groups are differentiated to three groups: owners, users, and society. Additionally, the parties contributing to the design and construction have their input on value (Salvatierra-Garrido et al., 2012). Thus, designers and construction professionals have a fundamental role in processing these collective requirements by defining, analyzing, and translating the explicit and implicit needs into design specifications (Kamara et al., 2002). According to Loughborough University and Partners report in 2003 about value in construction "The benefits of thinking about value are often not understood by all" and "to work effectively, people need to see the value in what they do" (Kliniotou, 2004).

Therefore, value results from negotiated and shared guiding principles to which all stakeholders shall subscribe; “When individuals collaborate to realize a common goal, projects are formed. A value system can emerge if values are expressed and shared between them" (Thomson et al., 2003).

To illustrate the value concept based on a real-world example, the Edmonton Public Library renovation project is presented (Figure 1-1). The city of Edmonton had recently renovated the public library in the downtown area to be a key social and creative hub for all community members. The main message was to embrace all community members and be inclusive. Thus, the core value of the project was the social value. This affected the vision of the physical spaces, the volumes, and the safety and security considerations. Accordingly, this core value was reflected in the design criteria. When we visited the library the inclusion message was obvious, different members of the community, including the disadvantaged or underprivileged, were given the right to read, engage with others, and use the computer labs for social connections on different platforms. Hence, this social value was obviously recognized by the end users of this facility.

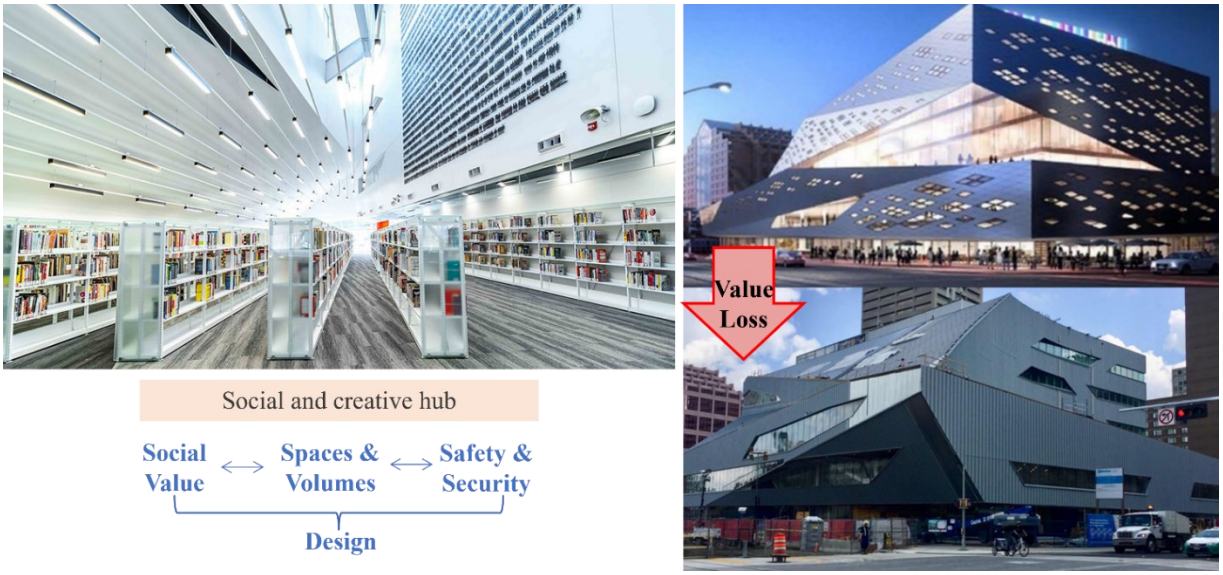

Figure 1-1 Edmonton Public Library as an illustration for the value concept (photos from Epl.ca, 2023; Martinez, 2019; Walter, 2019)

Additionally, this library has another good takeaway. The existing library facade was redesigned, and installation of a new cladding and curtainwall system was proposed through the 3D rendering. However, after the project was completed, the outcome was different, and it received a lot of criticism. This reflects what is known as value loss between what was envisioned during design and what was delivered after construction.

This example underscores another crucial dimension of the value concept. Value should be addressed throughout the entire project lifecycle and not just during the early phases. Existing research suggests that value is envisioned during the design phase, harnessed during construction, and experienced during use or operation (Devine-Wright et al., 2003). Consequently, the complete measurement of project value is realized at the project's final stage. A similar concept, known as Life Cycle Value Assessment (LCVA), aids in evaluating the economic and environmental impacts of a process or a product through their lifecycle (McCulloch et al., 2000). This method informs and guides better design decisions to minimize these impacts. Therefore, while value is experienced towards the operation phase, designers need to assess and investigate it early on to optimize project outcomes in terms of its intended value, including its economic and environmental value. It is also important to understand, as time progresses, both the design team and the client's understanding evolve, making it challenging to define all requirements at the project inception – a phenomenon referred to as the "fallacy of a 100% brief" (El. Reifi & Emmitt, 2013). Thyssen et al. (2010, p29) assured that "value is not something that can be made explicit once and for all", highlighting the limitations of current practices, specifically concerning the dynamic nature of value. Value changes over time based on different project factors that interact and change with project progression, influencing value perceptions (Khalife & Hamzeh, 2019).

To understand the value process during the different project phases, Figure 1-2 is proposed. The diagram illustrates the different phases in terms of value processes and highlights potential points where value losses could occur. The diagram serves as the contextual framework for this research, with specific focus on the 'value definition and capturing' phase and the 'value design' phase. These phases are central to understanding how value is perceived and shaped, and they play a critical role for having successful implementation of value in subsequent phases. The scope of this research is thus examining the value definition phase and the design development phase. Both phases contribute to value being translated into design solutions and setting the tone for the entire project. It is important to mention that misalignment between project owners and end-users is common (Stephan & Menassa, 2015), whether in public or in private projects. Therefore, an optimal approach is to engage end-users and operators early on. The inclusion of end-users and the public within the project team is essential for identifying project priorities and critical aspects that ultimately affect project outcomes (Fuentes, 2019). By delving into the identification of the value proposition list and teams' efforts to dealing with value during design, this research aims to propose and develop helpful methods and tools to conceive, articulate, and integrate value, ultimately shaping the project's outcomes and success.

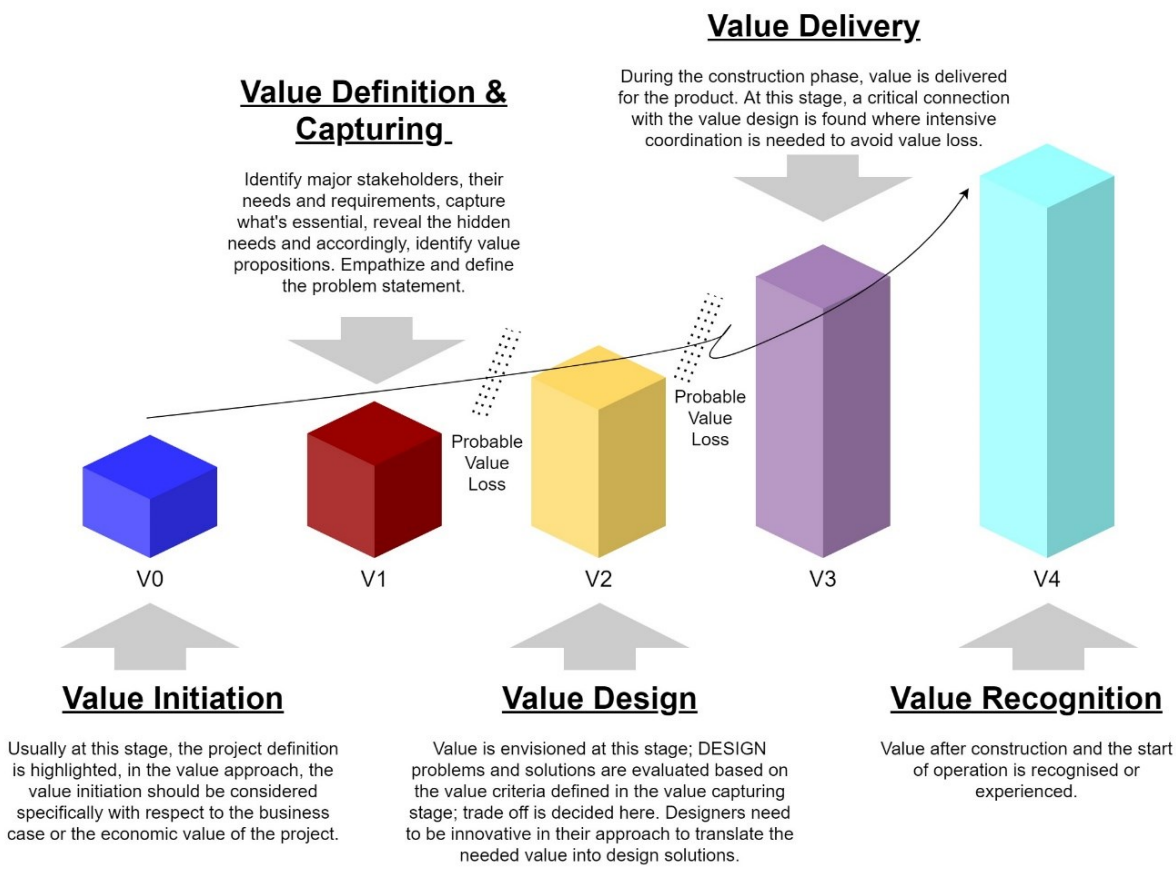

Figure 1-2 Overview of the project value process developed by the authors based on literature review.

1.2 PROBLEM STATEMENT

In the pursuit of investigating approaches for improving value delivery on projects, various challenges were identified, each of which will be targeted and addressed in this research. The highlighted challenges include:

- **Challenge 1: Vague and complex methods for developing and identifying value propositions and requirements on projects;** In the AEC literature, there is emphasis on the challenges faced by practitioners in identifying requirements and creating a clear project brief, which is subsequently impacting project performance (Vahabi et al., 2020). Pegoraro

and Paula (2017) identified critical factors affecting the requirements' identification process, including: the lack of open and effective communication, lack of clarity of the objectives, lack of precision in defining client's requirements, client's inexperience, difficulties in accommodating requirements of all involved stakeholders, among other problems. Additionally, identifying owners' requirements has been proven to be the major cause for change orders due to changes in their requirements and scope (Khoso et al., 2019). Thus, the lack of a clear process to develop value targets is a prevailing issue.

- **Challenge 2: Lack of measurements assessing compliance with the requirements and assessing value propositions** (Giménez et al., 2020); Key performance indicators have focused on assessing cost and time to plan and control projects, value-related indicators and measures have been scarce and behind, except for some performance measures related to customer satisfaction (Rashvand & Zaimi Abd Majid, 2014).
- **Challenge 3: Overlooking crucial human-centric interactions and social aspects on projects and often prioritizing only technical aspects;** the study of social dynamics includes examining factors, such as communication, power dynamics, leadership, and team dynamics influence on project outcomes. The lack of coordination and communication between project parties is considered among the major causes of poor performance on construction projects (Gamil & Abd Rahman, 2023). It is hard to understand communication channels for multiple teams involved without reliable tools and good visualization. By studying these interactions, project stakeholders gain valuable insights into the dynamics of the team, identifying strengths and areas that require attention or development. Project managers can thus benefit from tools that facilitate understanding of teams' network

structure to create a conducive environment for design discussions and ultimately achieve the intended value on projects.

- **Challenge 4: Improper planning and low ability to assess value fulfillment based on the different influencing factors on projects;** there is often value loss associated with the improper planning and tracking of performance against identified value attributes. The literature emphasized the importance of understanding the context of value, encompassing aspects like scope, timing, schedule, and constraints (Kelly, 2007). The intricate interplay between team dynamics, project setting, and value delivery remains understudied due to the complexity and mutual influence of these factors on each other (Pargar & Kujala, 2021).
- **Challenge 5: Improper exposure in the AEC education to the concept of value and its associated core practices that promote delivering projects with the satisfactory level of value attainment**; value management remains unrecognized in academic platforms, lacking a solid academic foundation, and suffering from a lack of understanding among the public, project owners, and organizations (Fong, 2004).

The challenges mentioned above present research opportunities, and the work presented in this thesis aim to tackle these obstacles by developing practical, simple, yet effective tools and strategies based on lean concepts, network theory, and digital simulation tools. The overall aim is to enhance the delivery of value on projects, benefiting all involved parties.

1.3 RESEARCH OBJECTIVES

To address these practical challenges, four main objectives were established. Extensive literature was conducted to identify suitable methods for overcoming these challenges. For instance, simulation techniques were found to be invaluable tools for understandings the interactions and impacts of different factors within complex systems (Macal & North, 2007). Therefore, agent-

based modelling was used to handle challenge 4. Moreover, research indicated that value generation in the design process can be improved using computer advanced visualization tools (Rischmoller et al., 2006). Therefore, such tools were utilized for resolving challenges 2 and 3.

The formulated research objectives and associated methods to tackle the mentioned challenges are:

- **Objective 1:** Develop and examine the usefulness of new methods, value classifications, and categories to help practitioners identify value propositions, perform trade-offs, and develop a customized value attribute list.
- **Objective 2:** Demystify the link between design team networks, social dynamics, and project value performance, and propose methods to quantify and visualize efficient design communication in relation to value, utilizing social network analysis.
- **Objective 3:** Quantify and monitor value fulfillment and alignment during the design phase by developing a simulation tool that models the interconnections between various social and technical factors that impact project value. This tool will also enable managers to test different scenarios and act as a value-based management tool that can better guide managers in their value-related decisions.
- **Objective 4:** Investigate the current architecture, engineering, and construction academic programs to identify potential weaknesses in teaching the value concept and propose a pedagogical framework to overcome the shortcomings.

The underlying research's hypothesis for the overall work is the following:

Utilizing the power of lean principles, digital technologies, and social dynamics has value improvement implications on projects and management practices.

1.4 THESIS ORGANIZATION

This dissertation consists of six chapters, introduction chapter (chapter 1), four chapters each focusing on one of the four objectives (chapters 2, 3, 4, and 5), as depicted in Figure 1-3, and a conclusion chapter (chapter 6).

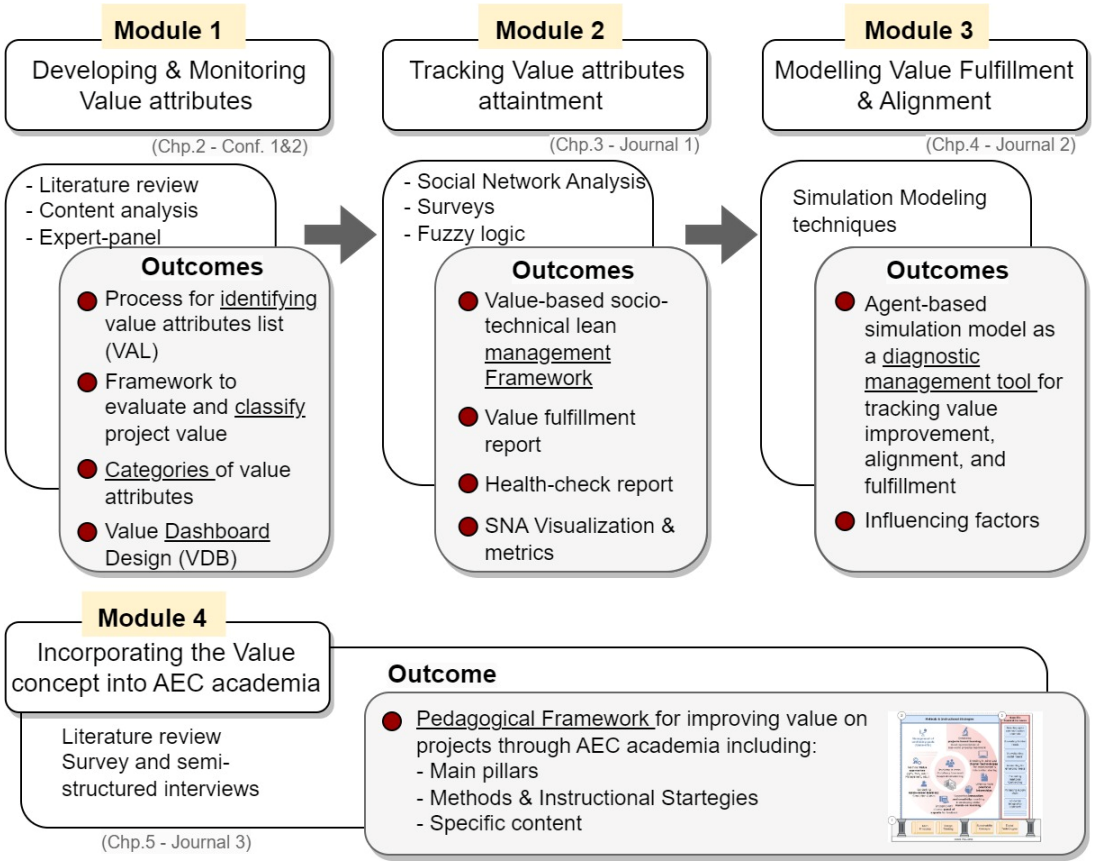

Figure 1-3 Thesis modules and outcomes from each module

Chapter 2 addresses the first objective, which involves developing and identifying value attributes. The main output from this module is a proposed framework for identifying the value attributes list and for classifying these attributes. A value dashboard is also suggested for tracking agreements.

Chapter 3 delves into module 2, related to the second objective, and presents a framework for assessing value propositions and quantifying design communications using network approach. The

main outcome of this part of the study is developing a value-based socio-technical lean management framework that presents three management practices, (a) reporting on value fulfillment report, (b) following up on health-check report, and (c) examining SNA visualization and metrics.

Chapter 4 explores module 3 and presents the simulation model developed to provide insights into value fulfillment and alignment based on different influencing factors extracted from literature and affirmed by experts.

Chapter 5 discusses module 4 in relation to the fourth objective, which focuses on investigating the AEC curricula concerning the value delivery concept. The main outcome of this module is the proposed pedagogical framework.

The first three modules (1, 2, and 3) are interconnected, with the output from each module serving as input for the subsequent one. These modules are practical in nature and are directly related to industry. Two projects were used to serve as case studies for the three modules. The first is a wastewater treatment facility, under an Integrated project Delivery Contract (IPD). The second is an educational facility under the Construction Manager at Risk (CMR) contract. Module 4, however, is more theoretical and focuses on academia. It serves as an establishment for improvements in industry practices explained in the first three modules, since changes in practice and the industry often stem from advancements in academia, which shapes future practitioners.

1.5 RESEARCH ENVISIONED IMPACT

Under the umbrella of having construction projects more socially, environmentally, and culturally impactful, this research strives to make projects people-centered and inclusive through (a) providing a voice for users so they develop a sense of belonging toward the project by prioritizing

engagement in the design process, (b) stressing on social and cultural value propositions of projects to support marginalized communities, and (c) empowering project teams through providing methods for analyzing their interactions and communication behavior thus addressing any challenges and identifying areas that require attention.

Additionally, the research is also part of the global efforts to have digital delivery of projects that fosters collaboration. Using a dashboard, simulation modelling techniques, and social network analysis with its metrics and embedded algorithms, the research leveraged the use of digital tools for achieving the bigger picture of delivering projects with value to their clients, users, involved teams, invested stakeholders, and affected surrounding communities.

Finally, this research is part of the Lean construction thinking that prioritizes people specifically in the transformational era of digital technologies and the uptake of Construction 4.0. The construction industry needs projects that contribute to the wellbeing of people.

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Chapter 2: Developing Value Attributes and Tracking Early Value Alignment

This chapter serves as the theoretical foundation upon which the research is built. It lays the groundwork for the subsequent research in chapters 3 and 4. Specifically, this chapter encompasses the exploration of two key aspects: examining and developing standardized methods for identifying the value attributes list (part 1) and monitoring early alignment among design participants by creating a dashboard for value alignment check (part 2). Establishing the Value Attributes List (VAL) is considered fundamental for delivering value. Thus, to answer the question of how to develop the VAL, a set of guidelines and steps were provided. The process was constructed by performing action research and engaging the two case studies explained earlier. This research section also provides a generic list of value attributes to be the starting point for the project team. The list included the major categories to be considered on projects. Findings suggested that developing a customized team-led list is particularly important and pursuing a clear direction on the subsequent steps for monitoring is required. The second part advises on the main steps to evaluate and classify project value, then proposes a design for a value dashboard to track value alignment on projects. The suggested dashboard acts as a visual management tool to guide project managers with the decision-making process considering the evolving understanding of value. The advocated value dashboard for the design phase is discussed and vetted with experts from the construction industry.

PART 1 – DEVELOPING PROJECT VALUE ATTRIBUTES: A PROPOSED PROCESS FOR VALUE DELIVERY

2.1 INTRODUCTION

At the onset of projects, owners or developers typically go for consultation to determine important decisions including the decision to launch their projects. Project initiation is an important phase authorizing a new project (Project Management Institute, 2004). Business cases and feasibility studies are thus prepared based on the general vision offered by owners and sponsors. With the project's goals in mind, the owner's team would identify a set of general requirements and limitations called Owner's requirements. Here the owner value proposition is equivalent to the business case and the reasoning behind the project initiation (Hjelmbrekke et al., 2017). Then, Project Objectives are developed which embrace the funding requirements, Base program, Added Value incentives Items, Base target Cost, Final Target Cost, Milestone Schedule, and any other objectives agreed to by the parties (CCDC 30 Integrated Project Delivery, 2018). Therefore, with complex projects and in a fast-changing environment, the vision and project goals need to consider the wider perspective of different teams and stakeholders (Laursen & Svejvig, 2016). The general requirements and the needs of different stakeholders are thus harder to compile on the onset of projects. To this end, the recognition and creation of value on construction projects is directly dependent on clear strategic thinking (Normann & Ramirez, 1993) including the engagement with diverse stakeholders and meeting their needs.

The briefing exercise has been a major process performed to identify the needs, desires, and aspirations which are translated into design criteria and design concepts (Ballard & Zabelle, 2000). The exercise includes a meeting that encompasses the key stakeholders. The result of such exercise is a brief, which is a formal document that records the needs of the involved parties. However, concerns about end-users' needs being generally overlooked are reported, leading to end-user dissatisfaction (Pemsel et al., 2009). Other concerns are discussed in the literature

including the impact of project brief clarity on project performance (Vahabi et al., 2020). Additionally, Pegoraro and Paula (2017) identified the critical factors affecting the requirements' identification process, including: the lack of open and effective communication, lack of clarity of the objectives, lack of precision in defining client's requirements, client's inexperience, difficulties in accommodating requirements of all involved stakeholders, among other problems. The study also provided some guidelines for overcoming such problems within design, focusing on information clearness to define objectives. Nonetheless, the study suggests future research to investigate more the requirement engineering and requirement management practices. Moreover, additional research was called for to maximize value creation for stakeholders with theoretical and empirical antecedents (Rojas & Liu, 2015). In short, requirements identification and value generation are interconnected concepts; thus, there is a need to revisit their approaches to identify them in a coherent manner.

While identifying owners' requirements might be thought of a basic and clear process, practitioners expressed their concerns about owners avoiding the detailed identification of their requirements to prevent future change orders, as they are proved to be the major cause for change orders due to changes in their requirements and scope (Khoso et al., 2019). Additionally, the problem lies in either the inability of the client in describing their needs, or the unconsciousness about the exact requirements and desires, with some needs surfacing late in the process (Wandahl, 2004). Moreover, the lack of a clear process to develop the value targets is also a prevailing issue. In this research, we will be focusing on the phase where the owner had gone through the steps of establishing the preliminary vision and goals of the project, and now there is a need to develop a set of attributes representing the requirements and needs of the different stakeholders and what they value. Different stakeholders in building perceive projects' value differently and have diverse

requirements (Haddadi et al., 2016). Though these value considerations depend on the involved parties and the nature of the project, identifying some general and basic concepts connected to the value of building projects as perceived by different stakeholders is needed. The literature calls for maximizing the environmental, social, and economic value of projects as part of the sustainability trend and demand, however, it overlooks the other core value attributes justifying this that it is context dependent. The main problem is that value attributes impact one another and are correlated which mandates the need to explore them in a structured inclusive way, to avoid the challenges imposed by overlooking the diverse values of myriads stakeholders. A need to investigate who is interested in what, and who is responsible for attaining the value attributes is vital.

Consequently, the research herein is trying to answer the following questions: (1) What are the basic and main value considerations discussed in literature and need to be considered on a project? And (2) How to identify a customized clear and inclusive value attributes list that reflects what is needed to have a successful project? The research contributes to the body-of-knowledge by proposing the essential early steps needed for preparing a solid and cohesive project value attributes list and advising on the topics that need to be considered for this list. The list is considered the foundation for delivering successful projects in terms of their intended value. The literature had focused on the subsequent steps in the value delivery framework, therefore, aiding the initial steps within the process was needed.

2.2 LITERATURE REVIEW

2.2.1 The Value Delivery Concept

The concept of maximizing value has been regularly called out to in the construction engineering and management literature. Specifically, maximizing economic, environmental, and societal value of the built environment is regarded as a trend and as a vision for the next 50 years

(Levitt, 2007). Authors have then examined the numerous terms that were adapted in the construction literature in reference to value in the built environment. Thus, to resolve the discrepancies and the inconsistency, Barima (2010) conducted a study on the "best term which (if fulfilled) can be used to mean value in projects". Results revealed three main terms: goals, standards, and needs as a representation of value on construction projects.

Benefits realization is another concept in relation to value generation, where the main challenge for generating value is understanding the project holistically and 'generating benefits aligned with strategic intent' (Tillmann et al., 2012). Mainly, value delivery includes fulfilling goals, desirable, and standards, achieving end-users' and teams' satisfaction, meeting project purposes, and addressing hidden needs and intangible objectives (Barima, 2010; Haddadi, Temeljotov-Salaj, et al., 2016). Understanding the value concept and the value delivery context is the first step towards pushing for improved practices for achieving higher value on projects and from a life cycle perspective. Value delivery is not a straightforward process but offering guidelines and best practices would help in getting towards the goal. Value is dynamic by nature, so it tends to change throughout the project (Khalife & Hamzeh, 2019). Yet, the initial process of identifying the general value attributes during the early conceptualization of projects would help in avoiding changes downstream and increased costs (check "MacLeamy curve").

2.2.2 Core Values and Value Trade-Offs

Core value is a common terminology used in companies or businesses offering services and/or products. On top of the core values come social responsibility and customer service. In construction, core values are discovered in different studies.

Emmitt et al. (2004) presented six key areas for value: Beauty, Functionality, Durability, Suitability (for the site and the community), Sustainability (respect for the environment), and

Buildability. This value hierarchy is considered as the project's objectives. Then through workshops, the team would specify the sub-objectives. A distinction between process and product values is highlighted in the literature, where market value and utility value are types of product value, and the process value is related to the ethical value which focuses on the performance and relation between teams (Wandahl, 2004). Another research project, called "Oscar – Value for User and Owner of buildings", highlighted the means which contribute to value creation (economic incentives, knowledge, contract, and processes and assurance quality), and identified 4 characteristics contributing to value creation: economic value (investment cost, core business cost, etc.), social value (people and organizations), environmental, and physical (space and infrastructure) (Bjørberg et al., 2015). Zhang & El-Gohary (2016) developed a value hierarchy that is based on the trio environmental, social, and economic value, and 50 sub-values were assigned to these categories.

Hjelmbrekke et al. (2017) explained about the importance of governance on enhancing value. They suggested a governance framework model with the following key components: strategic need (why questions), strategic effect (what questions/business perspective), project success criteria (intended outcome: user effectiveness and project efficiency), suppliers project business model (how questions: design team plan to align outcome to owner's needs), and project business model (how: metrics/ KPIs).

Kheirandish et al. (2020) presented a comprehensive value framework for design and collected more than 500 responses on the Human Values Survey. Nine value groups were identified: carefulness, justice, ecology, respect for others, meaningfulness, status, pleasure, respect for oneself, and personal development. This value framework is meant for designers to widen their perspective on human values, so they address these in design.

Moreover, given the fact that requirements change during design development and the fact that conflicting needs exist on any project, a recent study by Serugga et al. (2020) suggested a design decision support model based on the utility theory to assess the changing requirements, compare competing alternatives, and predict emergent needs. In fact, conflicting needs on projects are pushing research to offer tools that help design teams in the trade-off exercise. Arroyo (2014) discussed in details different multiple-criteria decision making (MCDM) methods to help designers in their decisions to select sustainable alternatives and explained the advantage of the choosing-by-advantage (CBA) technique. CBA was recommended and tested on different studies; it proved effective in helping teams understand value vs. cost and that trade-offs between factors are not linear (Arroyo, 2014). Additionally, studies have been exploring models to measure value creation on projects and prevent value losses. Huovila et al. (1997) advised teams to (a) closely coordinate with owners about their requirements, (b) use systemized management tools for the requirements (for instance use quality function deployment (QFD), and (c) collaborate with all participants generating design and construction information (Huovila et al., 1997). These suggested practices, along with other improvement tools, such as interactive coordination, checklists before/after design, and value stream mapping, are expected to generate improvements in the design process and prevent loss of value on projects (Freire & Alarcón, 2002). Likewise, Giménez et al. (2020) proposed a value analysis model which helps in value loss identification through proposed indexes. The approach is important as it suggests a quantitative method for identifying value loss.

With these different studies and attempts to provide categories, value listings, and approaches for emergent needs and value loss identifications, this research builds upon these ideas and take one step forward as to identify the initial steps and guidelines to customize the list of

value attributes. In this research, we define the value attributes list (VAL) to be the collection of project vision, guiding principles, and stakeholders' needs by compiling both process and product value propositions to guide the design decisions.

2.3 METHODOLOGY

The objective of the present study is twofold; first, offering a generic list of value attributes as a template and starting point for discussion among the project team, and second, providing the recommended steps to develop the customized list of value parameters then follow up on the process of value alignment and attainment. To attain these objectives, the action research approach was adopted. Action research focuses on contributing solutions to a problematic situation by testing research and proposed methods in real life practice; it includes five phases: diagnosing, action planning, action taking, evaluating, and specifying learnings & reflections (Susman & Evered, 1978). The steps of the methodology are described in Figure 2-1. By following the action research approach, the proposed list and steps were validated in the action taking process discussed in the two case studies.

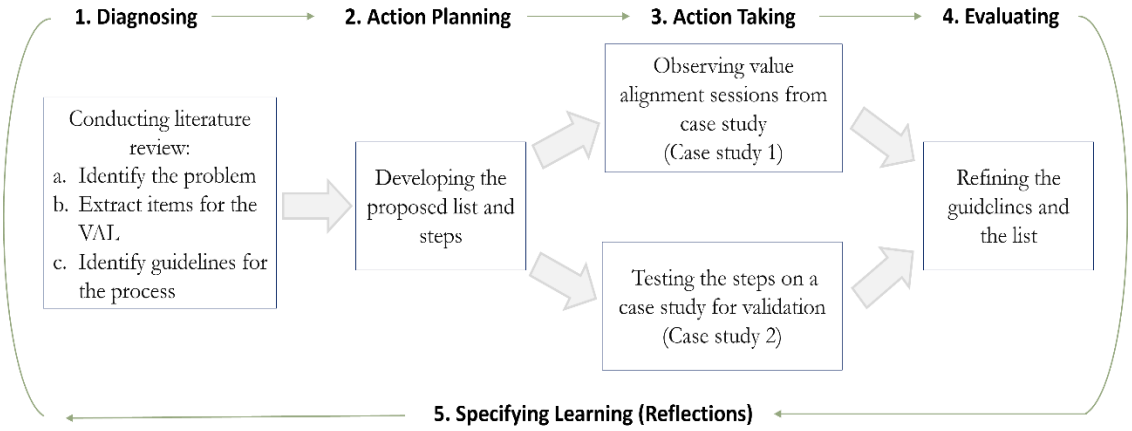

Figure 2-1 Action Research Methodology

The first step is diagnosing (1), it includes identifying the problem. As explained earlier in the introduction and literature, there is a need to advance this area specifically in relation to

developing a substantiated team-led list and informing practitioners on the steps and best practices to do that. The problem lies in the unstructured methods usually performed in practice. After identifying the problem and the need for proposing solutions, the subsequent step was conducting an extensive literature review to extract the core values that are generic to any project. The construction management literature offered separate lists which we tried to consolidate to produce an extended collective list. Some guidelines and preferred practices were also extracted as part of the diagnosis and exploration. Then, the final list and the proposed steps are put together as part of the action planning step (2). Afterwards, for the action taking phase (3), two case studies were employed to (a) observe the value alignment sessions and assess them to extract best practices, and (b) implement and test the proposed process developed as part of the suggested action plan. Based on the results from the two case studies, the evaluation phase (4) was conducted. It involved assessing the outcome, thus far, from implementing the suggested process and then refining it as necessary. The final phase was specifying learning (5) by performing reflections on this implementation.

2.4 ACTION PLANNING: GUIDELINES AND THE PROPOSED PROCESS FOR IDENTIFYING VALUE ATTRIBUTES

In the attempt to investigate what are the major attributes to consider on a project in coordination with the team and extended list of stakeholders, and what are the attributes that guide the decisions while evaluating the different design alternatives, several rounds of literature review was conducted by two of the authors. Based on what is offered in the literature, more than 135 identified keywords and factors were considered as essential on projects. Some of these keywords were similar in nature and therefore, the related terminologies were gathered under 31 categories. Another round of revision concluded to 16 value families, as revealed in Figure 2-2. The authors acknowledge that this list is not necessarily comprehensive as it is not a result of a meta-analysis

or scoping review aiming for exhaustive searching. However, the authors acknowledge the particularity of different projects and their considerations. Nevertheless, the completeness of this list is not the aim of this study, instead, the aim is to produce a list to help project managers or consultants in leading the discussions about value attributes on projects. Therefore, the need for this list is pertinent to checking the areas that need to be investigated among the project team.

Beyond this list, actions need to be conducted and steps need to be followed in order to develop a customized list of what is of value for a specific project from the perspective of different parties. The key for this process is coordination/collaboration. Whether in a traditional setting, or in an integrated project delivery setting, the list of value attributes shall be generated beyond the sole requirements of the owner. Additionally, another important aspect of this process is the realization that the list might keep updating during the development of the project, as per the nature of projects and the dynamic nature of value which is affected by perceptions, values, needs, and desires. However, the last responsible moment is a concept to be kept in mind for revisiting the core items in the VAL. Then comes the notion: if everything is important, then nothing is important. Keeping this in mind, negotiation is an important process in value assessment. While we identified 16 different families for the value attributes, consolidating the list is an important step through trade-offs and negotiations. The CBA method mentioned in the literature is a good practice for selecting among alternatives in value attributes.

The detailed steps in the proposed process are represented in Figure 2-3. As a start, two main prerequisites are needed to launch the value discussions. First, the owner and his team should draft the Owner's general needs, goals and vision for the project based on the business case. This would include the owner's perspective on what he values for project success. This step is the first in terms of value elicitation on a project. The second prerequisite is obtaining the agreement of the

Owner's requirements and needs with the project steering committee, where the team check if there is other pertinent information to add. Acknowledging the fact that the Owner could not identify the complete list of requirements and needs at the beginning, and that some information would be unknown to them, the process of value formulation is extended over several phases.

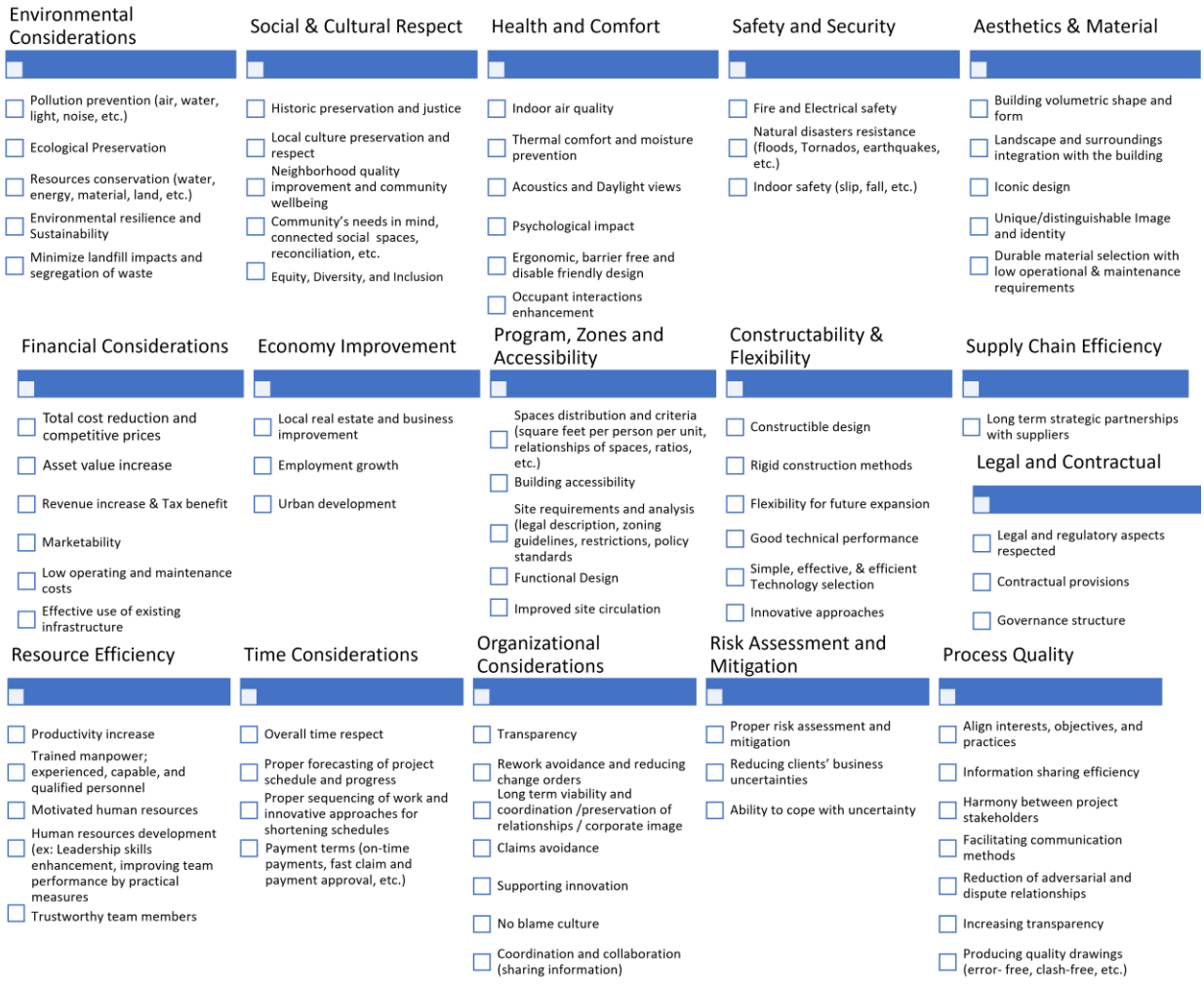

Figure 2-2 Value Categories (compiled from literature and studies by (Bjørberg et al., 2015; Emmitt et al., 2004; L. Zhang & El-Gohary, 2016))

The first phase of the process is identifying the teams or stakeholders and it is a preparation step where an advocate for value attributes should be assigned. The advocate could be in-house from any of the Owner's or consultant's team members. They need to be a knowledgeable

individual who would lead the discussion and dig into the heart of the stakeholders' values and needs. Their first mission though, is the identification and then classification of stakeholders as: manage closely, keep satisfied, keep informed, and monitor. With the stakeholders list ready and the Owner's general needs obtained, phase 2 – Generating the preliminary list, could launch. The project steering committee and the advocate could discuss the preliminary list offered in this chapter. For end-user involvement, representatives from different users should be identified and they would be identified as the user groups. They shall provide their opinion and feedback on the VAL. The evaluation criteria are as follows: indicating the obligatory (regulations, codes, standards), essential (important features), desired (good to have if the budget allows), neutral (indifferent about having it), resistance (against this value attribute or not desired) (Khalife & Hamzeh, 2022)

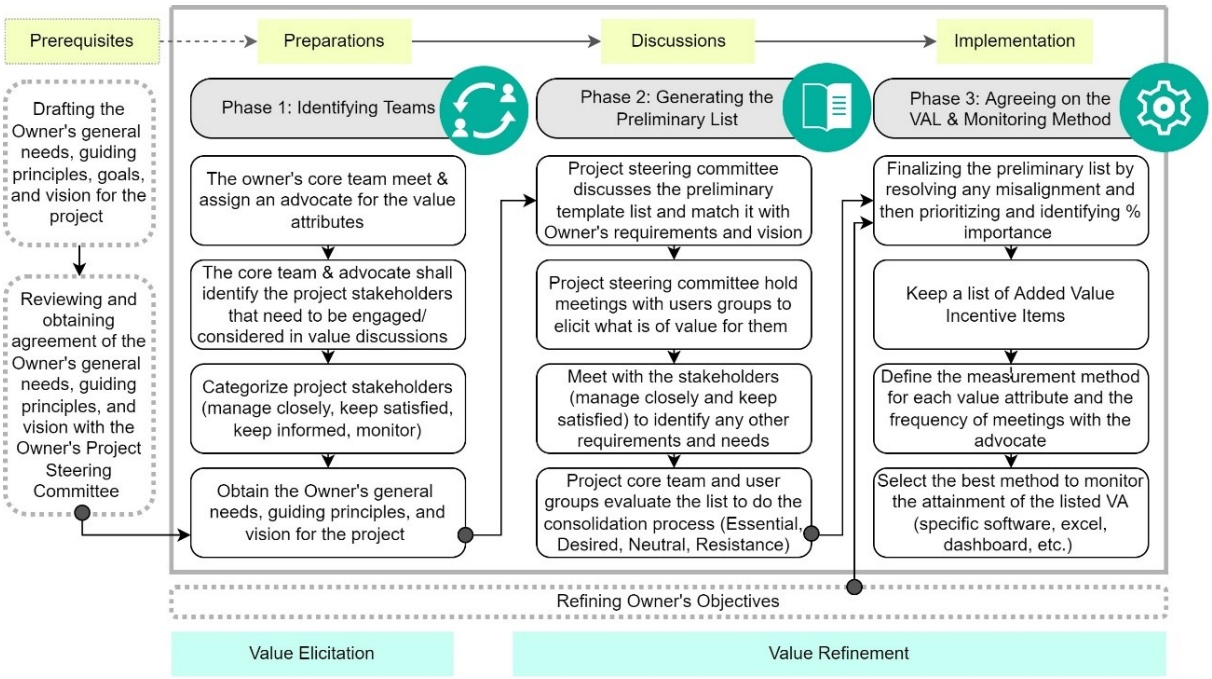

Figure 2-3 The process of developing Value Attributes List (VAL) and subsequent steps.

After consolidating the list and soliciting stakeholders' views and input, phase 3 can commence. Note that during the different phases of this process, the Owner's objectives are being refined and revisited as more information from different parties is revealed. In phase 3, the preliminary list needs to be finalized by negotiating any identified resistance or misalignment between participants. Then, the team members should identify the % importance of the attributes. In addition, a list of Added Value Incentive Items should be shared with the team to include any item they deem good to include on the project if budget permits.

The last two steps in the implementation phase are (a) defining the measurement method and/or the evaluation criteria for each attribute (KPIs, leading and lagging indicators) plus the frequency of meetings to follow up on value attainment; and (b) selecting the best method to monitor it or the format for filling the evaluation, so specify a computer program or software that will be used (excel sheet, a dashboard, etc.).

2.5 ACTION TAKING, EVALUATING, AND REFLECTIONS

2.5.1 Project 1 – Observing

Project 1 is the first of the two case studies employed for validating the proposed process. For this project, the authors used observational research, where researchers observe participants in a natural situation. One of the authors started attending the Design Coordination & TVD weekly meetings, and the value alignment bi-weekly meetings. These meetings were hosted by one member of the Project Management team who is also one of the authors. The project is a public services facility and is performed under the Integrated Project Delivery contract. The Project steering committee met to develop the Owner's requirements and goals in 2019 and then the validation phase commenced in January 2020. The resulting validation report included the Basis of Design and indicated that the IPD team is committed to applying Lean principals and pushed

for five key drivers: continue to generate value as seen from the Owner's perspective, focus on process and flow efficiency, look for and strive to remove waste, continuously improve as a team, and optimize the whole and not the parts. The contents of the report also included the regulatory requirements, Owner's requirements, goals and constraints, project values, and project cost (all under the Project Objectives).

Project values were described under 4 headings: General, Behavior, KPIs, and Sustainability. The General category included operational excellence, resilient design, social responsibility, and project satisfaction. 13 subheadings were described under the 4 headings apart from the items under sustainability. Every other week, the team would meet and evaluate one of the 13 listed value attributes. The values assessment includes pluses, deltas, and reflections pertaining to this specific value. *Mentimeter* is used, where each participant evaluates "how are we doing as a team in relation to this value attribute" and give a score out of 10. The team would be distributed into breakout rooms as meetings were held virtually during COVID. Each group discusses the plusses and deltas and writes them down in the "Virtual Values Assessment Template" document. The team would come back to the main session, and one representative would summarize the discussions.

Observing these meetings and discussions has shown that it is important to keep track of how the team is doing on project values. These meetings reflect "*the IPD Team's 'commitment' to the project during regular intervals: are we doing what we said we would do?"*. One observation is that participants need to be reminded of why they are doing this, in order to keep them motivated to participate and express their opinion. Additionally, one concern remains about the actions taken after reporting the results to the Senior Management Team (SMT) at the monthly SMT/PMT Report-out meetings. For this reason, the guidelines highlighted the need for a value advocate to

keep track of the needed improvements and take the necessary actions to address any shortcomings.

Finally, the project manager on this project, and based on his experience and involvement on this IPD project, suggested another categorization for the value families. It included 5 basic categories: (1) behavior values, (2) budgetary values, (3) experiential, (4) operational, and (5) sustainability values. He also highlighted the importance of outlining good practices and guidelines that would help owners in developing the Project objectives (the prerequisites for the process explained in this chapter).

2.5.2 Project 2 – Testing

Project 2 acted as an application for the proposed process to validate its applicability and suggest adjustments based on this experimentation. The project is an educational facility within a university that is seeking to have this building serve as a 'crossroads for the university community'. A historic building is being renovated to accommodate new spaces and modern infrastructure, along with a newly constructed adjacent structure.

Two of the authors got on board with the project management office of the university. The topic of value delivery grabbed their attention. The research team and the project manager coordinated to produce the list of value attributes based on the: (1) key project drivers, (2) programming principles, and (3) Core & Shell (C&S) guiding principles. The participating research team delivered three presentations about the importance of value discussions and value delivery on projects, to the PM office, to the project steering committee, and to the Executive Oversight Committee EOC. This helped in getting buy-in from the whole team to support the process. The main incentive for this collaboration was seeking end-user satisfaction. The project management team is also looking for measurable ways for evaluating project success. While the

project is not under the IPD contract, the team is striving for a collaborative approach and an IPD spirit.

The implementation process followed the same steps expressed in the process of Figure 2.3. Up until the drafting of this research section, phase 2 has been completed, while phase 3 is yet to be implemented. Figure 2-4 (a) shows that discussions around the generic list were performed to match the guiding principles and key project drivers. Figure 2-4 (b) shows the first evaluation of the value attributes related to “team behaviors” (scale out of 5).

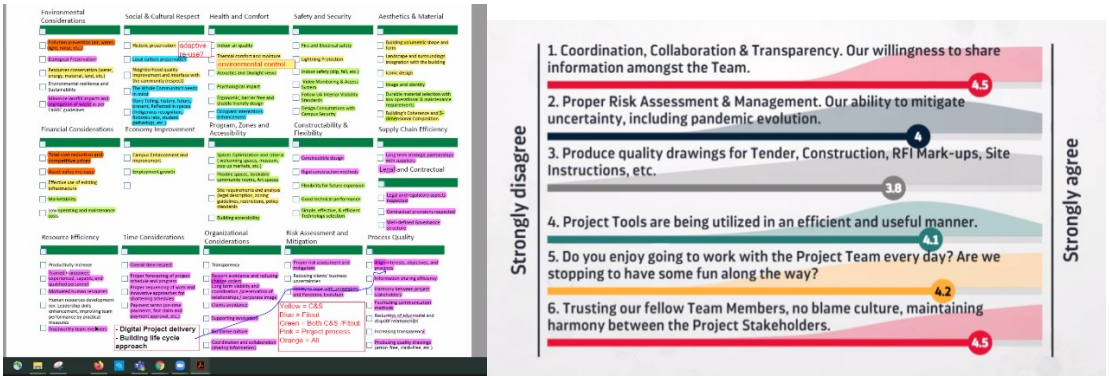

Figure 2-4 (a) Discussions with the PM based on the generic list and highlighting the attributes in connection with the educational facility; (b) first evaluation of the value attributes list under the team behavior category (using Mentimeter)

The value discussions revealed some conflicting interests which reflected the need for further negotiations. Usually, when such cases surface, the team would be innovative in their approach, and creativity would be higher leading to thinking outside-the-box. The project manager expressed some concerns over participants’ actual review of the list, and their approval that it reflected their needs rather than being a pre-prepared list that fell as a ‘parachute’ on them. Other concerns were recorded regarding how to avoid subjectivity during evaluation. As indicated earlier, and based on those concerns, the authors recommended an advocate that would keep reminding the team about the importance of this exercises, keep them engaged to feel they are

committed to this list, and agree on how to translate subjective matters into more objective targets and measures.

2.5.3 Reflections

We present in this section the general reflections about the process and lessons learned from the case studies. These are presented in the form of a set of recommendations for practitioners. The following steps are thus necessary:

- Specify the network of people that need to be engaged at each stage (ex: when discussing the evaluation of *process* value attributes – transparency , team coordination, etc. – these are more related to the core design team not user groups).
- Agree on the general categories upfront, the subheadings under each category could keep changing due to the dynamic nature of project values.
- Ask the right questions to determine the benchmark (propose a set of questions)
- Describe value attributes in a clear language and maybe identify glossary.
- Identify how to translate these value attributes into design elements.
- Keep track of contradicting value attributes and apply trade-off techniques such as CBA. Keep also track of any value losses (refer to studies in literature section). Report lessons learned.
- Keep the team fully engaged. The team should know that this is not an additional burden/exercise to the project, it is part of the process for achieving success on projects similar to risk management, for instance. The team should also feel ownership of the value attribute list, as they shall be part of the development process, or at least they should be given the chance to provide feedback on the list.

2.6 CONCLUSIONS

The need for a well-defined foundation for developing the value attributes list has been regularly asked for whenever the topic on value is raised in front of practitioners and scholars. In this chapter, we presented a preliminary list to be the starting point for discussions on projects. The list needs to be revisited when coming across different types of projects and should be customized to meet the stakeholders' focus. While the list is not comprehensive in its whole, the authors argue that the headings are sufficient to raise the dialog needed for detailed specific subheadings. One of the reasons for not having an exhaustive ready-to-go list is the nature of value attributes being subjective and context specific. Nonetheless, this list can help novice practitioners looking for a starting point to launch discussions and guide the negotiations on value. The chapter also outlined practices and guidelines to help develop the customized extended list and keep track of its implementation along the project design development and construction phases. Two case studies were presented, and discussions were conducted to benefit from their experience in implementing these practices. Future studies will tackle in depth the prerequisites and steps for helping owners develop their needs on complex projects. This chapter adds one layer to the body of knowledge pertaining to delivering value on projects by highlighting the steps for developing a vital list of what is important to stakeholders on a project.

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PART 2 – DEVELOPING A VALUE DASHBOARD FOR TRACKING VALUE ALIGNMENT DURING DESIGN

2.8 INTRODUCTION

The construction industry has been witnessing an increased attention to delivering value to different project stakeholders (Laursen & Svejvig, 2016); yet, complexity on projects is resulting in challenges that require further research attention (Martinsuo et al., 2019). Practitioners have been striving to coordinate the diverse value perceptions to reduce conflicts on the one hand (Kelly et al., 1993), and to evaluate the design decisions and value fulfillment based on the different requirements on the other hand (Ballard, 2000). Accordingly, having organized and systematic frameworks and models to manage both the requirements and the value creation process is a prevailing need (Laursen & Svejvig, 2016).

Value creation is considered a relatively new focus in the construction industry in comparison to the attention given to time, cost, and quality on projects. Researchers are calling to have a shift from the product-centric criteria of specification, cost and time, to the value-centric notion where the crucial dimension of value is added to the traditional project management triangle (Winter & Szczepanek, 2008). In fact, confusion between quality and value was observed among construction professionals (Thomson et al., 2003). However, investigating the research trends in construction literature in connection to value and quality studies over the last 20 years revealed an increase in value-focused studies especially in the last 5 years and a departure from the traditional view of quality (Aliakbarlou et al., 2017).

While key performance indicators have focused on assessing cost and time to plan and control projects, value-related indicators and measures have been scarce and behind, except for some performance measures related to customer satisfaction (Rashvand & Zaimi Abd Majid, 2014). One main reason is the ambiguity associated with value in relation to its diverse

interpretations on projects (Barima, 2010). Nonetheless, several methods were discussed in the literature that can be a starting point for providing input and assessment tools for value delivery.

Lean thinking has been conceived as an important driver for the increase in productivity in the AEC industry based on minimizing waste, improving value, and enhancing flow on projects (Liker, 2004). Lean practitioners have been emphasizing, for a long time, the importance of delivering value on projects and providing methods for achieving this aim using target value design, set-based design, integrated design, and integrated project delivery, among others. Additionally, with the increased use of automation and digitization, it is important to utilize the power of technology to help track and measure indicators on a project. A plethora of studies have provided such digitalized help for tracking cost and time considerations on projects. Per contra, tracking value delivery and generation is not well supported. Automating the process and having a clear visualization helps project managers take the necessary actions in a timely manner to steer the project into the right direction of delivering more value. Visual management plays an important role in lean as well, where it is a fast and reliable mode of communication that supports shared understanding and situational awareness (L. J. Koskela et al., 2018).

While the existing research and practices offer methods to understand the needs and derive requirements on projects to enhance value delivery, tracking the attainment of value and visualizing it along the project progression is still lacking. In fact, agreeing on what constitutes project value is still rudimentary where extensive workshops are organized (Emmitt et al., 2004). Instead, this approach should be updated to include guided strategies that foster the use of technology and visual methods for easier tracking. Accordingly, this chapter presents a guided framework for value identification and offers the design of a visual interface to help practitioners – design managers and owners' representatives- in assessing their design with respect to value

achievements. This dashboard acts as an early notification tool and a pro-active value assessment process to guide the design decisions on projects as necessitated by the needs and requirements of project parties and within the constraints of each project.

2.9 RESEARCH BACKGROUND

The literature had elaborated on two major points in relation to this research: (1) Building success is measured by the extent to which it fulfils its purposes and the requirements of the key stakeholders; and (2) Visualization of project performance and progress of design would facilitate and benefit the decision-making process (Tillmann 2018). Moreover, value generation had been regarded as a paramount and critical factor to projects' success. To this end, the following subsections describe some of the leading approaches that help in the value delivery process.

2.9.1 Value approaches discussed in literature.

Value management is one of the prominent strategies discussed in the literature as part of the methods focusing on enhancing value delivery on projects. Value management advocates for regular workshops to discuss value parameters (what is considered value to the project) and then explore adequate solutions to meet the requirements in a cost-effective way (Kelly et al. 1993). Value management practices intend to optimize value relative to costs on projects, yet applications have often ended up reducing costs rather than increasing benefits (Laursen and Svejvig 2016).

The Quality function deployment method (QFD) is another method for better managing clients' requirements on construction projects. QFD facilitates the "identification, structuring, analysis, rationalization, and translation of explicit and implicit client requirements into solution-neutral specifications for design purposes" (Kamara et al. 1999). Moreover, target value delivery (TVD) is considered a strategic way of delivering projects by including a set of tools based on lean management principles; TVD enhances value in a continuous process starting from the pre-design

or project definition phase to set the target (Zimina et al. 2012). Other methods that are important to highlight from the literature beyond construction, include:

- Objective and Key Results (OKR): a method for defining and tracking objectives which is adopted by several leading companies. OKR encourages transparency among teams thus motivating them to improve performance and communicate together about the completion of targets set by companies or projects (Hao and Yu-Ling 2018).
- Hoshin Kanri (HK): a management methodology to align vision and strategic goals with tactical goals and daily operations throughout the levels of the organization. Each level would create plans and targets based on the higher-level performance. A ten-step process is found for HK planning and implementation (check Nicholas 2016).

2.9.2 Metrics and indicators that represent value delivery on projects.

The literature was explored for metrics that help in measuring and evaluating project value. Thomson et al. (2003) provided the design quality indicator (DQI) as an assessment tool supporting project management systems to ensure the delivery of value during design. Khalife and Hamzeh (2020) provided measures that can be tracked on projects to evaluate value in two settings, one to forecast if managers are on the right track of delivering value using the leading indicators (ex: percentage agreement after meetings) and another to explain the actual achieved value using lagging measures (ex: fast client approval cycles). Additionally, the literature distinguished between the **product value** (the value attributes related to the physical facility) and the **process value** (the attributes that focus on the delivery method, relations between teams, performances, and managerial procedures). Both are important for the successful delivery of the project and the satisfaction of stakeholders. Moreover, there is a need to differentiate between tangible and intangible requirements, and between subjective and objective measures which impact value

delivery and alignment on projects. Accordingly, with the literature setting the cornerstone for measuring value on projects, a visual tracking method that can utilize technology for tracking value throughout the project and highlight the actions needed by project participants is essential.

2.10 METHODOLOGY

The methodology followed is the Design Science Research methodology (DSR). DSR proposes an artifact that solves a certain problem in a specific field or context. The aim of this research is to help practitioners in enhancing value delivery on projects by providing a framework that includes the design of an interactive interface (dashboard) that shows value changes on a project and updates on alignment based on meetings outcomes and project progression. The dashboard includes a set of existing and developed indicators and measures to help in the process of controlling value delivery to guide actions on projects. According to Hevner (2007), three major cycles are encompassed in DSR: (1) the relevance cycle, where the new artifact intends to set improvements in the practices of an environment and where field testing is required; (2) the rigor cycle, which provides existing knowledge, expertise and artifacts found in the application domain to ensure its innovation beyond the known; and (3) the central design cycle, which supports the iterations in the design and evaluation of the artifact until reaching a satisfactory product. Consequently, this research presents the framework and the dashboard development as artifacts for improving value delivery on projects using visual tools. Part of it is based on existing research, however, it extends beyond it to ensure systematic performance and tracking of project value. For the evaluation, expert opinion is employed to assess the framework and dashboard design. Accordingly, two iterations of modifications for the dashboard were performed based on the expert's feedback. Future studies will include the actual application on a case study.

2.11 COLLECTIVE STEPS TO EVALUATE AND CLASSIFY PROJECT VALUE

The main objective of this research is to propose a design for a value dashboard, intended to assist project managers in the assessment of their design decisions throughout project progression against value requirements. This dashboard serves as a tool to gauge the alignment of these decisions with the specified value requirements while promoting coordination among diverse project teams. However, before presenting what is on the VDB, some preparatory steps are needed to support the value delivery and the tracking process. Implementing the dashboard successfully is closely linked to attaining these steps beforehand. The steps are discussed hereafter and represented in Figure 2-5.

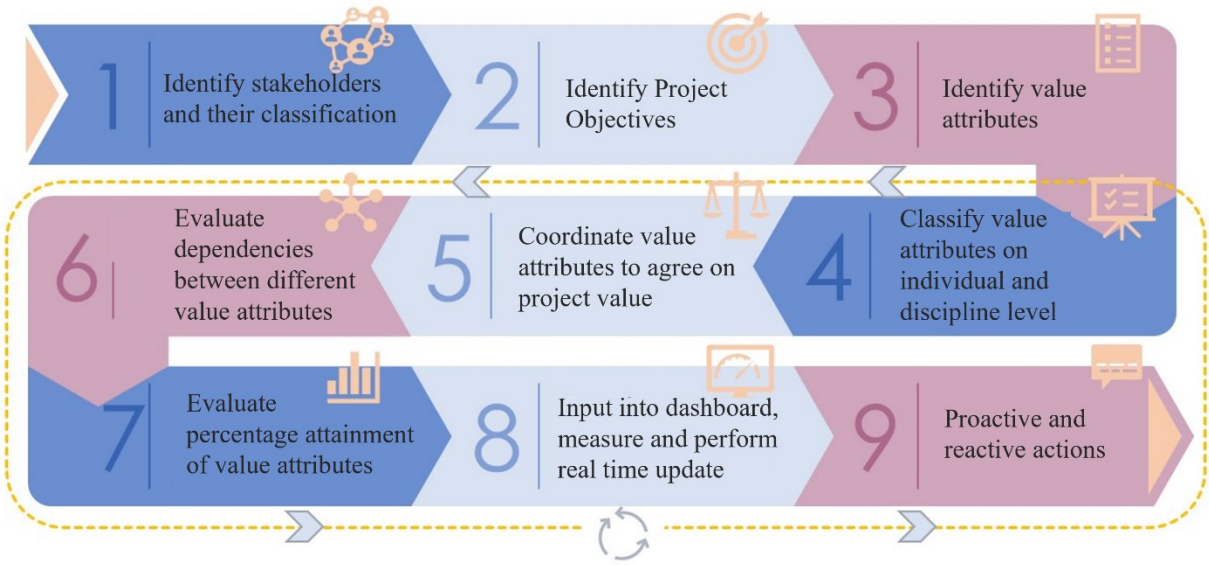

Figure 2-5 Framework showing the steps needed for enhancing value delivery on projects.

1. Identify stakeholders and their classification; Aapaoja and Haapasalo (2014) provided a framework to do so through four phases: (1) define project purpose and identify constraints; (2) identify project stakeholders based on their functional role; (3) assess stakeholders' ability to contribute and impact the project; and (4) classify the stakeholders into four groups: primary team members (key players), key supporting participants (keep informed), tertiary stakeholders -

external (keep satisfied, ex: Public authorities), and extended stakeholders (minimal effort, ex: suppliers). Other studies show three categories of stakeholders on construction projects: responsible, impacted and interested stakeholders (Zhang and El-Gohary 2016). According to these classifications, a chart shall be made to identify whom of the stakeholders to satisfy, whom to inform, whom to monitor, and whom to work with. This step would help in organizing the stakeholders' performance during the design phase and their level of engagement needed.

2. Identify project objectives; whether based on the briefing exercise or the indicated client purposes, the major project objectives shall be identified and explicitly stated. These represent the foundation for the value attributes. Project objectives are the higher-level requirements. Project value attributes are more specific, detailed, and diversified (they are focused on both the process and the end-product). Project value attributes are also subjective by nature and need to be coordinated to meet the project objectives and goals.

3. Identify value attributes; collect the value parameters or attributes that are important for the project from the perspectives of different stakeholders. The following points shall be considered:

- Differentiate between process value and product value;
- Indicate probable constraints for achieving the corresponding attributes;
- Identify the intangible and tangible parameters, then translate the intangible ones into equivalent tangible objectives; for example: 'maintaining good reputation' can be translated into high number of sales before building completion- which is measurable;
- Indicate the relative weights of these parameters and their importance;

A projected list of value categories is presented in Figure 2-6. Sixteen main categories were identified based on an extensive literature review and based on practitioners' input. These categories are usually reflected in the design criteria. The purpose of identifying this list is to

present the main streams of value parameters that every project would consider. This would help different stakeholders in highlighting what is important for them out of these considerations.

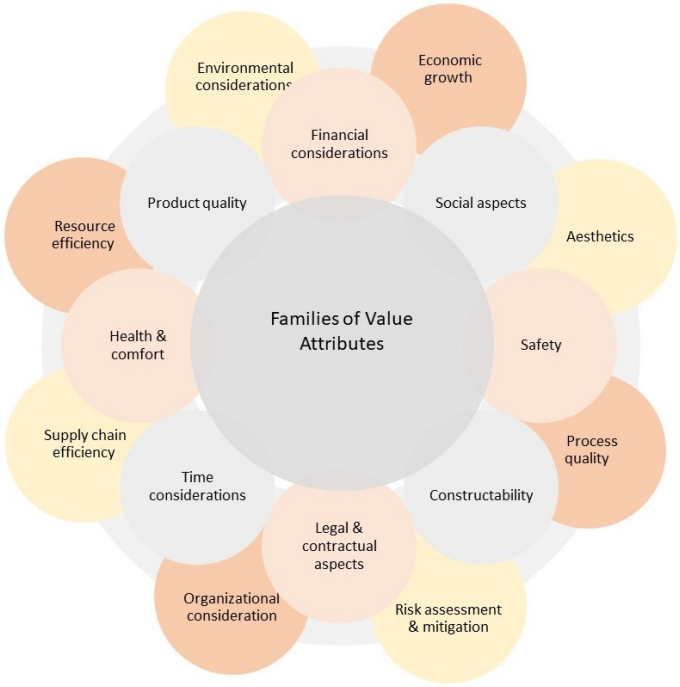

Figure 2-6 Families of value attributes on construction projects

4. Classify value attributes; *On an individual and discipline level:* it is important to classify the requirements according to the classifications shown in Table 2-1. The literature offers other classifications to customer requirements based on the famous Kano model and questionnaire, whereby requirements are described as attractive, indifferent, must-be, one-dimensional and reverse (Huang, 2017). Based on these levels, a more specific classification is suggested. Obligatory value parameters are related to the regulations and standards per discipline. Essential parameters are what the owner or parties perceive as important features on projects. The desired attributes are good to have, but it depends on the budget and other parameters by different stakeholders. Then there are the neutral value attributes for an individual or across a discipline level, where parties are indifferent about having these on the project. Finally, parties could classify

some value parameters as resistance, where they are against having these attributes on a project. These might be reflections on what the owner initially requested on a project or what other disciplines are requesting. Therefore, trade-off and intensive collaboration should be performed to resolve these attributes. With these steps, parties are moving to the project level.

Table 2-1: Value classifications

Classification	Description
Obligatory (O_i)	Regulations, code, standards…
Essential (E_i)	Important features on the project
Desired (D_i)	Good to have
Neutral (N_i)	Indifferent
Resistance (R_i)	Against

5. Coordinate value parameters to agree on project value; At this stage, all disciplines and key stakeholders would collaborate to agree on the core value considerations or the critical value attributes specific to the project (Eq.1). These are made of the obligatory and the essential parameters identified earlier across different parties (*i.e.*: key stakeholders). Then the expected value would be identified representing the core value plus the desired (Eq. 2). Then there is the potential value that is the summation of the expected value plus any revealed value that was hidden earlier and was revealed along the process of knowledge sharing and coordination (Eq.3).

$$\text{Core\_Critical value: } \mathrm{CV} = \sum_{i=1}^{n}(\mathrm{O}_i + \mathrm{E}_i) \quad (1)$$

$$\text{Expected value: } \mathrm{EV} = \sum_{i=1}^{n}(\mathrm{O}_i + \mathrm{E}_i + D_i) \quad (2)$$

$$\text{Potential value: } \mathrm{PoV} = \mathrm{EV} + \text{revealed value} \quad (3)$$

The purpose of coordination on a project level is to reach a shared understanding and align the different perceptions of value. Therefore, it is important to agree on what is core value or mission critical. These core value attributes would be inclusive of different parties' requirements.

6. Evaluate the connections between the different value attributes; in this step, the project teams shall define the relation between the different value parameters. Similar to defining the dependencies between activities on a project, it is important to define connections to understand how attaining this value attribute will affect other attributes. Using the fuzzy logic used in (Bashir et al., 2020), the authors recommend visualizing these dependencies in the dashboard.

7. Input evaluation of percentage attainment of the value parameters; after each meeting, design change, or specific time progression, the project team shall evaluate the percentage fulfillment of the value parameters. Translating the value attributes into design requirements would help identify the percentages. This would help in assessing the overall project value fulfilled so far on a project from the total expected.

8. Input into dashboard, measure, and update in real time; following the systematic application of the previous steps, project managers shall input the information into the proposed dashboard (VDB), to visualize the results and analyze them.

9. Evaluate proactive/reactive measures and take actions; the next step after analyzing the dashboard results is to evaluate what proactive and reactive measures shall be taken to improve project value delivery. The actions needed shall be recorded and concerned parties shall be informed.

The loop in the framework (Figure 2-5) shows that at any point in time a change can happen throughout the process of defining and categorizing new value parameters in the design

development phase since value on projects is dynamic and tends to change with the proliferation of more information and with coordination among the extended supply chain.

2.12 THE PROPOSED DESIGN OF THE VALUE DASHBOARD (VDB)

The value dashboard design is based on the previously mentioned steps. Figure 2-7 represents the proposed design of VDB. Mainly, the dashboard interface includes 3 divisions: the first is for inputting the value attributes, the practices followed on a company and project level, and the KPIs with their scores; the second division represents the visual tracking of: (a) the dependency between value attributes, (b) the changes within the different value classifications based on interactions and project progression, and (c) the overall project value achievement represented as a percentage gauge; and the third section is for actions needed based on the real-time updates and graphs.

For the first section, project managers shall input to the dashboard what value attributes are regarded as obligatory, essential, desired, neutral, or resistant at the onset of the project. This is performed across disciplines and across the different identified key stakeholders as per step 1. Automatically, value attributes classified as resistant, where one party does not desire these, will be updated in the conflict section, and need to be resolved. The dashboard would then show the number of value attributes that need to be resolved between different teams. While it is common to have attributes that relate to several teams, the main concerned parties should take the lead and resolve it. Best practices for this matter, and based on lean principles, are to have cross-disciplinary team coordination, big room discussions, and integrated design with trade-offs. The next level would be across the project. Here, the value attributes are categorized as core value attributes, expected value attributes and potential value. At this level, attributes are to an extent agreed on, or

part of team alignment was reached, where foreseen conflicts were mitigated. Nonetheless, continuous updates need to be inserted.

Having dynamic value considerations on projects, updates shall be made to keep track of changes in core and expected value from the project on a weekly, monthly, or occasional basis – as needed. Also, revealed attributes or new value attributes shall be tracked with project progression. This would help in the overall calculation of value and for future references in similar projects.

Additionally, project managers need to discuss the dependency between different value attributes according to the following categories: no dependency, very low, medium, high, very high and complete dependency; the network diagram will be automatically generated after defining these and based on the calculations in (Bashir et al., 2020). Though these networks are usually developed for project activities dependencies, it is important to understand, in a similar manner, the connections among different attributes of value. This would help in interpreting the focus areas or attributes that are considered hub in which they affect several other attributes on project, or those that have higher dependency thus actions should be prioritized accordingly.

The dashboard design also considers the leading and lagging indicators that would help in assessing the situation during design and consequently making formed decisions to enhance project value. Leading indicators have checkboxes to check which practices are actually being implemented from the recommended practices on such projects. Lagging indicators are the KPIs (Key Performance Indicators), where teams are asked to score those KPIs based on the actual project progression. The average value will be visible on the dashboard and low KPIs will make project managers aware of the need for action.

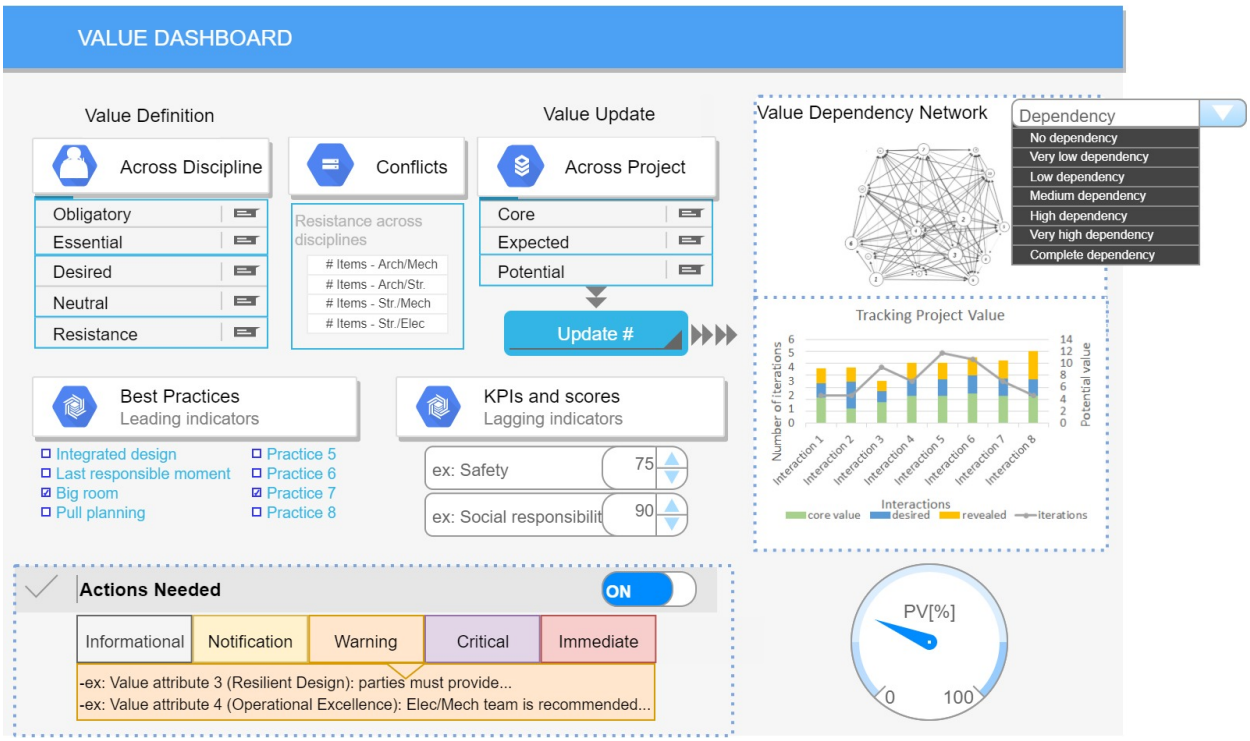

Figure 2-7 The Value Dashboard (VDB) design

Actions needed on the project are represented at different levels: informational, notification, warning, critical, and immediate actions. These levels represent the severity of the action needed. An automated message shall be sent once this section is filled with the type and the description of the action. Finally, the percentage gauge of project value will directly indicate the total project value achieved thus far based on the attributes and their weights. It is to be noted that within the scope and constraints of this section of the chapter, it is only possible to discuss the generic layout of the dashboard and its practicality. The dashboard design included a description of the needed elements to be tracked and information to be collected. However, the detailed explanation and presentation of equations, metrics, and measures that need to be included will be discussed in future studies.

2.13 VDB VALIDATION AND DISCUSSION

For the validation of the dashboard design, and since not all measures and metrics are ready for an actual implementation on a case study, an expert panel was consulted to get feedback on the dashboard importance and its foreseen practicality. The expert panel consisted of two experienced construction professionals (more than 15 years of experience), where the first expert (Exp1) is a lean expert that strives to enhance delivering value on projects, and the second expert (Exp2) is currently holding position as a project coordinator on an IPD project with focus on delivering value. Both experts expressed their support to having a dashboard and a mechanism to improve value alignment and delivery on projects as provided by this research, yet clearly stated that dashboards are "*not a sole mechanism*" (Exp1) and they represent "*only 20% of the story*" (Exp2). Exp1 elaborated that this should be part of a system of supporting elements such as TVD etc. as called out in the literature herein. Exp2 explained that the other 80% are how to socialize about the value attributes discussions, utilize the outcome of the dashboard, and keep updating the information. Exp2 mentioned that "*The dashboard becomes useless unless we put things into place*", therefore, they required an early mechanism for workshops or value sessions with the owner before the start of the project. While we mentioned the needed preparatory steps as described in Figure 2-5, which Exp2 highly praised, the very early stages of value workshops need to be elaborated on in supporting research which is currently understudy.

Additionally, both experts suggested specifying top value attributes or what Exp1 described as 'key anchoring points of value' that include the top project value definitions needed, explaining 'if everything is important, nothing is important' (Exp2). Therefore, the authors support the core value requirements be of top-tier value attributes. Exp2 highly supported the value dependency network and stakeholders' classifications, as understanding these vastly help in

managing the process. Both praised the value classifications and the family categories of value. Overall, both experts advocated the elements in the dashboard and showed interest in the future implementation yet questioned the 'maturity level' and the invested time needed from the various users.

2.14 CONCLUSION

The main objective of this research is to enhance value on projects by tracking value alignment and generation over time. Accordingly, a proposed design for a Value dashboard (VDB) was offered following recommended steps for execution. The dashboard currently includes some measures for evaluating project value without specific metrics. The purpose of these steps is to translate project objectives top to bottom in a funnel format, where top is the general objectives specified and bottom is the quantitative part where value is evaluated using metrics. Next chapter will address the tip of the funnel on the measurement part. Future work also includes the application of the VDB on projects to check its applicability. The research is also studying the possibility of including automatic real time update upon design developments and project progression using advanced technology and then connecting these to project time and schedule.

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Chapter 3: Demystifying the Dynamic Link between Project Value and Design Team Networks: A Socio-technical Lean Management Framework

This chapter aims to help project managers attain higher value on projects through analyzing and managing the social dynamics within project teams. Specifically, it explores the connection between design team communication and project value performance, as well as the evolving dynamics of value and network structures. The research introduces a socio-technical lean management framework to help practitioners monitor the attainment of the previously identified product- and process-value (as explored in chapter 2) and investigate value communication patterns. This exercise would enable teams to advance and align value propositions among stakeholders. The findings highlight that the inherent social dynamics and network composition can influence a team's ability to exchange knowledge and coordinate design tasks, ultimately impacting the fulfillment of project value.

3.1 INTRODUCTION

Construction projects are meant to deliver benefits, business outcomes and desired value for different stakeholders involved on projects. Project success is connected to the value created and a stronger focus on front end of projects is recommended (Laursen & Svejvig, 2016). Value is defined as the client's needs, where the client groups are differentiated to three groups: owners, users, and society. Additionally, the parties contributing to the design and construction have their input on value (Salvatierra-Garido et al 2012). Accordingly, at the onset of projects, the owner, or the business developer together with the consultant team shall identify a set of guiding principles that form the basis of the project's design. Alongside, a set of value attributes should be identified that describe the important considerations and commitments from the team related to both the

constructed facility or the product and to the execution process or the behaviors during performance. This set of value attributes reflects the project vision, guiding principles, and stakeholders' needs including those of the owners, users, design team, construction team, and the surrounding community (Khalife et al., 2022). Specifically, the team discusses what are important aspects on the project relating to environmental considerations, social matters, cultural aspects, and operational requirements. Agreeing on this list and attaining the value attributes is contingent on the level of collaboration on projects which is related to team dynamics. In fact, studies and research in the architecture, engineering and construction sectors have been focusing more on the importance of people as assets to companies and to construction projects. Project management practices have been calling for a high level of collaboration and team integration on projects as it has been proven to achieve higher rates of success and satisfaction compared to less collaborative approaches (Choi et al., 2019). Research has also called to study high performance teams rather than just focusing on the classic factors of time, cost, and quality (Chinowsky et al., 2008). This shift in focus in the project management approaches is still open for exploration.

Key Performance indicators (KPIs) are quantifiable measurements which have been long used to evaluate project performance with respect to schedule, budget, and specifications or quality. However, the new notion in project management regarding KPIs on projects is gone beyond this traditional view to represent the 'P' as people where KPIs on projects are to keep people interested, keep people informed, keep people involved, and keep people inspired. This research falls under the umbrella of managing and inspiring people to manage value delivery and thus achieve successful projects. To this end, lack of coordination and communication between project parties is considered among the major causes of poor performance on construction projects (Gamil & Abd Rahman, 2023). When parties do not agree on what is of value on a project and the way a

project needs to be executed, disagreements occur leading to rework and losing trust, thus jeopardizing project success. Thus, proactive planning efforts and effective team management practices facilitate reaching a common ground among stakeholders and subsequently enhancing success on construction projects.

Lean construction refers to construction projects as products and refers to the process of executing projects as a production process that needs to be efficiently managed to add value and eliminate waste (Ballard, 2000). When design and construction professionals think about project value, they need to make sure that their attention should not be merely about the product, rather, efforts should be made to think equally about the production process and behaviors. Specifically, the process needs to be integrative, inclusive, and based on trust. Design and construction teams should be able to deliver projects knowing what's needed beyond their technical responsibilities; that includes knowing the value they need to deliver considering the social needs of users and communities. This is only achievable when building team structures that establish the necessary communication channels that contribute to aligning team's value propositions. Within the digital technology era, and with the intensification of conflicting social and technical aspects of the emerging technologies, the focus on human-centric processes is more needed than ever.

3.1.1 Problem Statement

Research has been directing attention to managing and optimizing resources and technical aspects on projects. However, social aspects and team management have been generally less investigated and more of a fad. Additionally, the following problems are realized:

- There is a lack of structured methodology for identifying, tracking and assessing value on projects considering the social dynamics on projects;

- Despite the early identification of value, its development is usually lost through the project delivery process;
- It is hard to understand communication channels for multiple teams involved without reliable tools and good visualization;
- Some projects do not have the opportunity to be designed and constructed through an integrated project delivery, hence more guidance is needed, and strategies that help in fostering collaboration through effective communication techniques should be investigated.
- Project managers need tools that help them understand the dynamics in their teams to provide a good environment for design discussions. This would help in achieving the intended value on projects.

3.1.2 Research objectives and contribution

This research aims at investigating the link between project value fulfillment and team dynamics with the purpose of improving value delivery on projects. The research also explores communication patterns of design teams and their impact on achieving higher alignment of value. The specific research objectives are:

- Developing guided steps for tracking and assessing product-process value propositions during the progress of project design.
- Studying and visualizing team communications using networks approach and analyzing network metrics and modularity.
- Finding possible correlations between social network analysis metrics and value fulfillment levels reported.

The overall objective is helping project managers understand the dynamics of different teams involved in design and undergoing proactive lean measures to improve their communication,

connection, and value discussions. This is expected to better align value on projects and achieve higher satisfaction from the different stakeholders.

A proposed lean design management framework is presented that will help guide project managers to (a) identify project value then report value fulfillment and health-checks on projects, (b) develop social networks to assess and improve communications among teams, and (c) analyze networks on individual and group levels and identify communities formed. The research contributes to the body of knowledge through investigating the issue of value delivery considering the dynamic nature of both value propositions and social connections on projects. It presents the topic of improving value delivery from a socio-technical system perspective.

3.2 LITERATURE REVIEW

3.2.1 The need for value generation on projects and value-driven design

The concept of maximizing value has been regularly discussed in the construction engineering and management literature since advocating for value generation as being at the core of the design process (Green, 1994) and perceiving design as a process of generating value for customers (Ballard & Koskela, 1998). Since then, researchers highlighted the need for a value-based approached for managing construction projects; "construction, in order to fully benefit from project management best practices, has to liberate itself from the cost-based project delivery approach and move to a value-based approach" (Forgues, 2005). Levitt (2007) implied that maximizing economic, environmental, and societal value of the built environment is regarded as a trend and as a vision for the next 50 years. Moreover, international efforts to identify directions for future research in project management indicated the need to move from 'product creation' to 'value creation' as part of rethinking project management practices (Winter et al., 2006). "Management of Value" was offered as a new approach for organizations to articulate their value

priorities (Dallas & Clackworthy, 2010). Then, value-centered thinking and value management practices were called for on the management of projects (Laursen & Svejvig, 2016).

The Lean Construction Institute (LCI) puts emphasis on Target Value Delivery (TVD) as a driving force to increase value on projects by encouraging communication among the various team members. Setting clear goals to maximize value to stakeholders and minimizing production cost are all part of the TVD process (LCI, 2023). Value in Lean Philosophy is defined as what the end-customer wants; it is the customer's definition of value that counts. TVD practices put stress on collaboratively planning projects, selecting the right project team, and on having specific group dynamics as 'one team' that ease communication among them (Ballard, 2020).

More recently, the Project Management Institute had presented a new edition of the PMBOK Guide and indicated that the major shift in this edition is perceiving project management from a system view of value delivery and presented a new section on value delivery system (PMBOK® Guide, 2021). If anything, this shift in the management approach accentuates the importance of the methods that deliver value on construction projects.

3.2.2 Construction as a socio-technical system & Lean Design Management

Sociotechnical systems consist of interacting social and technical subsystems. Construction projects entail technical requirements that are meant to create value for society and users. When considering value-driven design on construction projects, designers are focused on the social needs and sustainability aspects of the built environment, thus, they are seeking the ultimate goal of achieving efficient buildings by collaboration of stakeholders from early design phases (Bjørberg et al., 2015). Human-centered design becomes the attention. Construction projects are temporary social arrangements that entail intensive communication and sharing of information specifically in the design process where every participant in design is dependent to an extent on other players to

complete their work and realize goals (Emmitt et al., 2004). Additionally, Emmitt and Gorse (2009) explained that communication channels emerge and develop through social interactions; teams enter into communication with diverse values and perceptions and therefore managing these communication attempts is critical to achieving higher value for money (Emmitt and Gorse 2009). Focusing on communication and project team features is thus inseparable from the value discussion. Lean design management aided in looking at design as a socio-technical process and exhibited approaches for achieving higher value on projects and better communication through stakeholders' representation, last responsible moment approach, set-based design, target value design, value management workshops, and collaborative cross-disciplinary work and co-location of teams (Emmitt et al., 2004). Additionally, lean knowledge management is concerned with value where the right information needs to be defined and delivered. It is imperative to have explicit techniques to evaluate value and then transform evaluation into improvement (Rooke et al 2010).

In discussing why socio-technical approaches shall be considered in systems engineering, Baxter & Sommerville (2011) indicated that "*the failure of large complex systems to meet their deadlines, costs, and stakeholder expectations are not, by and large, failures of technology. Rather, these projects fail because they do not recognise the social and organisational complexity of the environment in which the systems are deployed. The consequences of this are unstable requirements, poor systems design and user interfaces that are inefficient and ineffective"*. While these authors were discussing this narration in the software engineering industry, these conditions reflect what is happening on construction projects.

Finally, the high fragmentation and complexity of AEC industry projects necessitates collaboration that cannot be improved only through technology, yet it must be guided by the social phenomena of project teams (Phelps, 2012).

3.2.3 Communication and the use of SNA in construction for investigating team dynamics.

Project value is a complex concept that needs to be communicated with the launch of projects to achieve alignment. Griffith and Gibson (2001) discussed the top critical alignment issues that affect team alignment during pre-project planning. They identified having open and effective communication within the team and among stakeholders as critical to developing an adequate definition of project scope, objectives, and needs. A recent study explored the different factors that contribute to project complexity, and concluded that interactions between stakeholders, variety of the stakeholders' strategic goals, and inefficiency in project management practices, for instance *inadequacy of communication channels and poor coordination*, were found to be among the top factors (Bilgin et al., 2022). Moreover, given that stakeholders can bring value to the project, being positive or negative, their management is thus an integral area to project management (Pirozi 2017). Chbaly et al (2021) underlined communication as a factor to promote client value generation by presenting a framework for developing communication maturity. Echoing these studies, this research focuses on communication as a way to better align value on construction projects.

The literature has also focused on the dynamic nature of value where diverse interconnected factors play a role in shaping the expected project value including the mode of operation, team structures, and stakeholders' network (Emmitt et al 2004, Khalife and Hamzeh 2019). Having a dynamic nature, value is generated by reaching common ground and mutual understanding through enhanced communication (Khalife and Hamzeh 2019).

Accordingly, to better explore communication among project teams and stakeholders, the social network analysis (SNA) approach is suggested as a tool to help study teams' structure and interactions. SNA is a diagnosis tool that enables organizations to study teams' interactions,

communication, information flow as well as the strength of their relationship by displaying the interrelations in a network structure; it is also used to support implementation of lean construction (Herrera & Alarcón, 2023). SNA has been deployed to improve design processes, for instance by testing collaborative approaches supported by building information modelling and lean practices and their impact on reducing design errors (Al Hattab & Hamzeh, 2015).

Network metrics are an integral part of the quantitative analysis that SNA provides, besides the visualization analysis. These metrics are related to the network elements, which are (a) the nodes representing the parties involved in the SNA study and(b) the edges representing the connections between these parties, whether it is indicating communication, information flow, or a relation. Figure 3-1 explains these metrics which are two types, network-related metrics that explain the general network connection, and nodes-related metrics which are specific to each party or node. These metrics are used in this study and are part of the framework proposed in later sections.

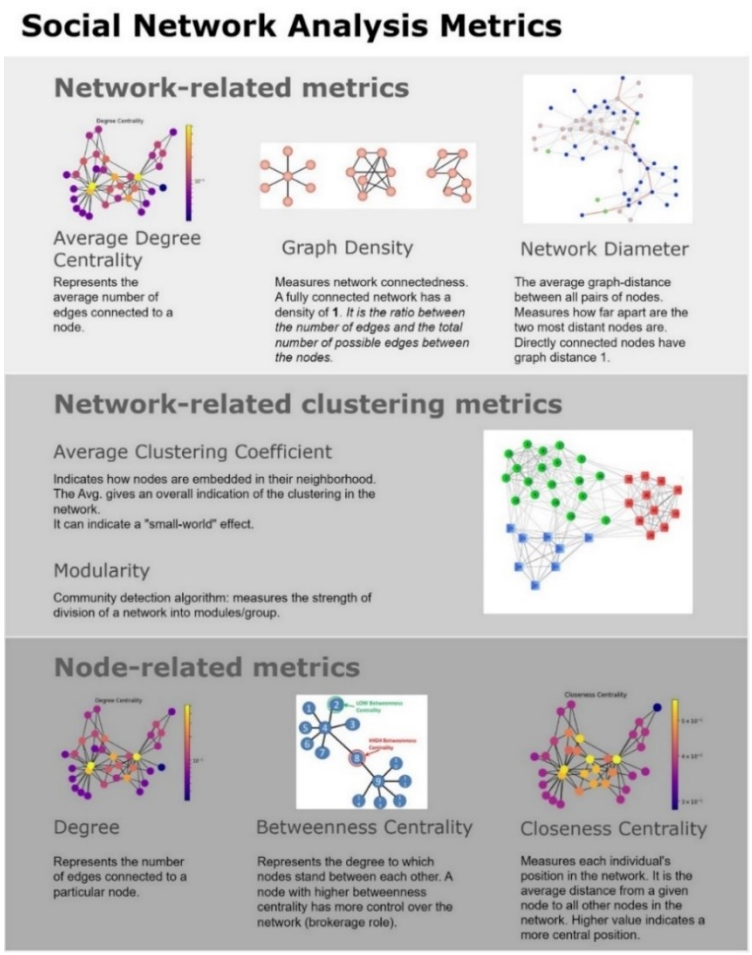


Figure 3-1 Social Network Analysis metrics

3.3 RESEARCH METHODOLOGY

The authors employed the Design Science Research (DSR) methodology. DSR aims at providing solutions by designing and making scientifically grounded artifacts that would address certain problems in a particular field. The artifact must be tested and validated to prove its purpose (Hevner, 2007). DSR has been investigated in construction management and has proven effective for developing and implementing innovative managerial tools (AlSehaimi et al., 2013). The steps followed in the DSR methodology vary according to the literature, yet mainly include identifying the problem, suggesting a tentative solution, demonstrating that the solution works, and identifying

the research contribution (Rocha et al., 2012). In this research, the authors identified the problem of value delivery on projects as being less explored from the social dynamics' aspect, where a need for novel management practices that contribute to value generation during design has been recognized. Accordingly, the authors advocated for lean value-driven solutions that tackle the problem from a sociotechnical angle. The authors proposed a lean design management framework that would enhance value delivery by considering the link between team dynamics and their design communication with project value performance. The suggested framework, acting as the artifact, was tested on a case study to prove its applicability and effectiveness. One of the authors attended design meetings during the design development phase over the course of a year and followed the practices presented in the framework. The authors intended to test the framework multiple times during different periods of the design phase. They worked closely with the project manager to identify the relevant dates for collecting data on team communication. After the third round, and with the end of the one-year period, the data collected were sufficient to perform the analysis on. The case study served as an approach to observe, test, and validate the various aspects of this management framework, where such a method is popular in similar cases (Yin, 2018). After refining the framework based on the case study, validation was performed by inquiring experts' opinion. Three experts were consulted about the framework. The experts were part of the case study, so they were much involved in the steps that were conducted and were consulted along the way on the adequacy of the methods to collect the data. After collecting all the approaches under one framework, it was logical to ask them for their feedback for validation. The framework contributions were recorded in this chapter.

3.4 A VALUE-BASED SOCIOTECHNICAL LEAN MANAGEMENT FRAMEWORK

3.4.1 Framework processes, tasks, and tools

The authors proposed a framework to demystify the link between team structures and project value and utilized the social network approach with lean practices as part of this framework. The developed framework was altered based on the case study. This section presents the framework with the tasks that project managers can follow and the tools they can use to make it reproducible to their projects. The proposed lean value-based design management framework is illustrated in Figure 3-2, and the steps for conducting the framework will be explained hereafter.

3.4.2 Step 1- Identifying value attributes.

During the project definition phase, the process of identifying conditions of satisfaction and what is wanted – or of value – on a project is conducted (Ballard 2020). It is part of deciding on what project to build. Additionally, value management workshops are usually performed to articulate a 'shared social reality' about stakeholders' requirements and construct a value tree, or value hierarchy (Green 1994). The objective here is to reach a common understanding of the project's social, environmental, organizational, and other value proposition aspects. Khalife & Hamzeh (2022) explained the steps needed to identify value attributes on projects: (1) identify stakeholders and their classification, (2) identify project goals and purposes, (3) identify value parameters by differentiating between process value and product value where teams need to think about different categories for value propositions (Figure 3-3), (4) categorize value parameters based on what is obligatory, essential, desired, or resistant against having these items in the list, and then (5) coordinate value parameters to agree on a final project value list or value propositions.

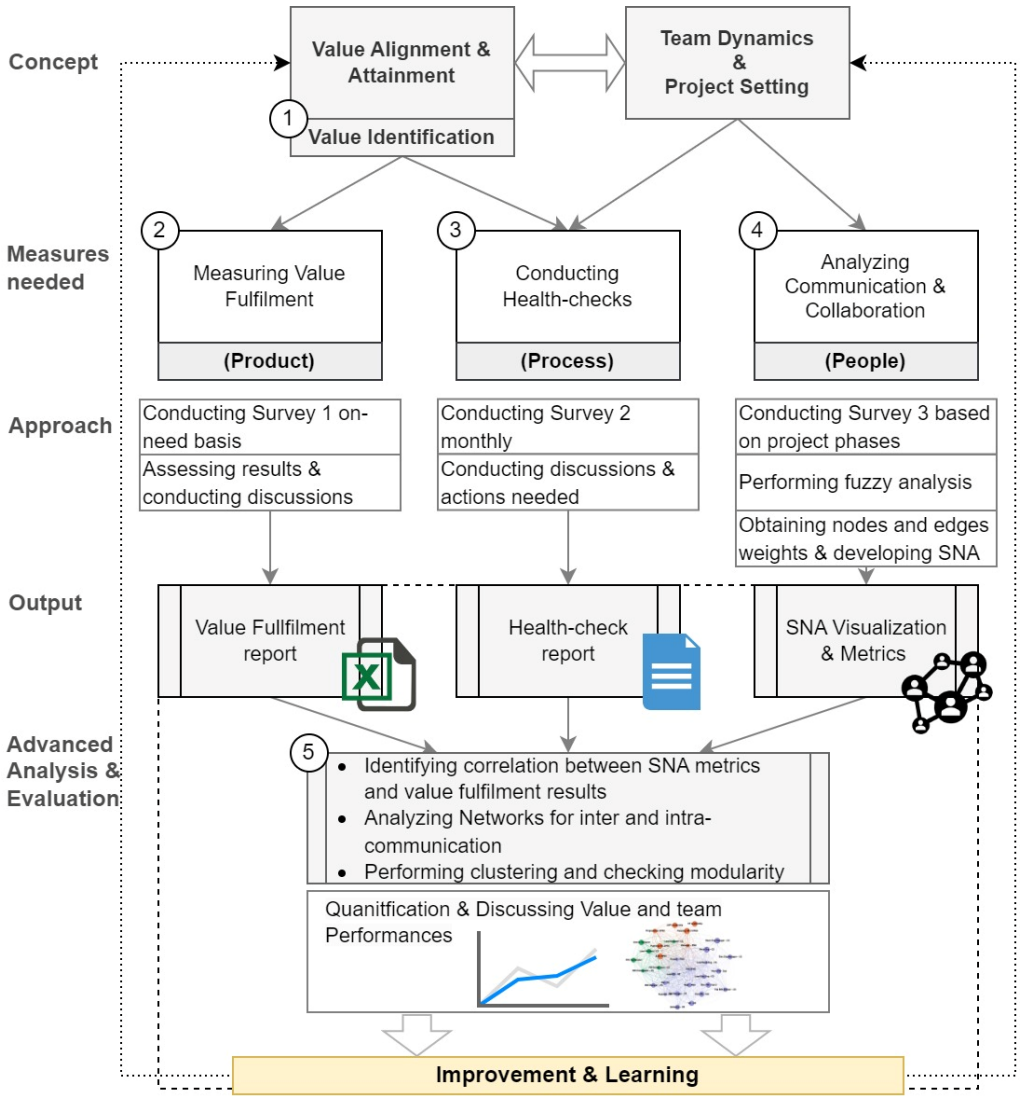


Figure 3-2 Proposed Framework

Once the value proposition or value attributes list is reached, the subsequent step includes tracking value attainment throughout the design process. For the product-related value propositions, step 2 in the framework will be conducted, and the project manager can prepare the value fulfillment report on a need basis. For the process-related value propositions, the team can evaluate these using step 3, which will be more frequently conducted to ensure the design process is as aspired by the team. In this study, and as a continuation of the previous study (Khalife & Hamzeh, 2022), the authors further develop the framework to track value fulfillment and

simultaneously study team dynamics and communication patterns. In Figure 3-3, a Venn diagram summarizes the categories proposed for the product and process value attributes based on available literature. Teams on projects can use the Venn diagram to organize their needs based on the proposed categories. They can always alter or add to the presented categories based on their project type and their specific needs. The proposed set of attributes is thus a starting point for teams to customize their own set of value attributes. Value negotiations and trade-offs are part of this process. In the Venn diagram, the commonality space represents the people's category, which fits in both the product and process categories. For the product, people represent owners, end-users, and the surrounding community, as for the process, people represent design and construction teams. When a project team discusses health, comfort, and well-being in the value identification phase during value management workshop sessions, they should consider how these factors will benefit everyone involved in the project, including those designing and using it.

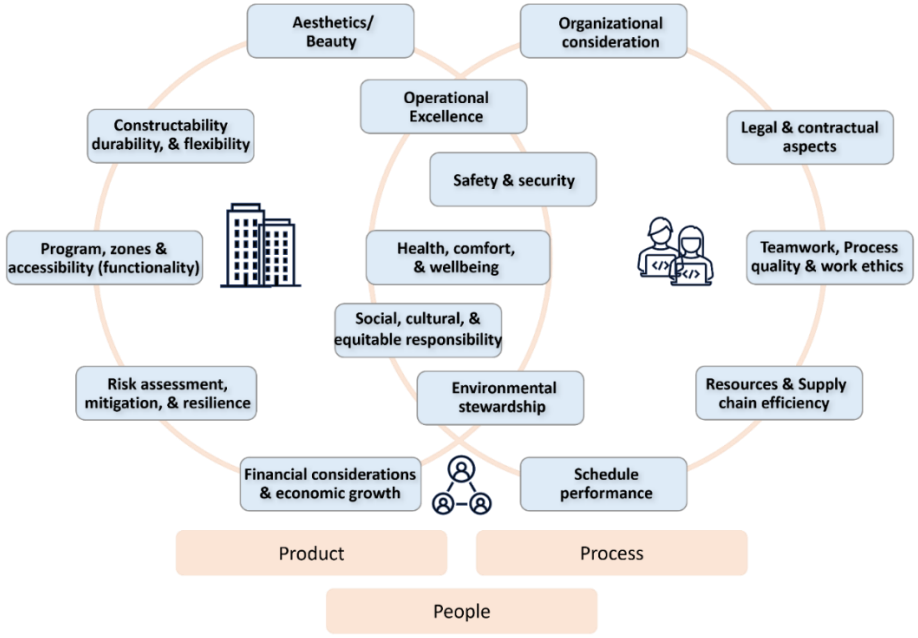


Figure 3-3 Fifteen Value proposition categories relating to the construction product and work process, including the people at the core.

3.4.3 Step 2- Measuring value fulfillment.

In stage two of the framework, the different teams involved in the design, including representatives from contractor's teams, end-users, and other stakeholders, shall evaluate the fulfillment of value attributes that were prioritized and agreed upon and related to the building or the product. The evaluation method could be as simple as recording the percentage fulfillment on a scale of 10 or 100 or conducting an advanced analysis based on (Giménez et al., 2020). For the simplified version and the purpose of this study, which is focusing on the social aspect and analyzing team dynamics, the authors developed a sample scorecard report as illustrated in Figure 3-4. The report includes the full list of value attributes identified in step 1 with two spreadsheets: one scorecard summary sheet for tracking the average obtained from the teams in all rounds (Figure 3-4-a) and another score check sheet to record the score in one round and reflect on each of the value attribute fulfillment scores by indicating the concerns, potential problems, or rooms for improvement, then indicating if action is needed and the parties responsible for it, then the follow-up date (Figure 3-4-b).

The authors developed three surveys for the framework. Survey 1, which elicits the evaluation from the team, includes two questions. The first is to evaluate value attainment through asking: “The team collectively laid out some important aspects for this project; please give a score from 1-10 (1= very poor, 5=neutral, 10= excellent) to how well and satisfied are you - so far into the design - with the team's achievement and fulfillment of these requirements, goals, and constraints. For items that are not yet discussed on the project, or you are not involved in attaining, please select 'Not in my purview”. The second question is gathering the rationale behind the low rating; it reads as follows: "Please comment on the evaluation listed above, specifically if you ranked some of the listed items as poor."

Core Value Attributes Fulfillment Report	Scorecard Summary		
Core Value Attributes	Score Check 1	Score Check 2	Score Check 3
	Date Month_year	Month_year	Month_year
Value Attribute 1	8.00	8.71	8.60
Value Attribute 2	5.71	7.00	4.86
Value Attribute 3	7.67	8.18	8.13
Value Attribute 4	5.59	4.38	4.60
Value Attribute 5	7.37	8.07	7.57
Value Attribute 6	8.11	8.64	8.45
Value Attribute 7	7.32	8.27	8.08
Value Attribute 8	6.00	7.93	7.80
Value Attribute 9	7.72	8.31	7.46
Value Attribute 10	7.63	8.55	8.67
AVERAGE VALUE FOR VALUE LIST	7.11	7.80	7.42
Added-Value Items (AVI)			
AVI 1	Recover	1_5	
AVI 2	Improve	6_7	
AVI 3	Sustain	8_10	
AVI 4			
AVI 5			

Core Value Attributes Fulfillment Report	Scorecard	DATE: Month - Year

Levels	Score Range
Recover	1_5
Improve	6_7
Sustain	8_10

Core Value Attributes		Score Check 1	Notes/Reflections: Why did we score it as such? Is there a problem? Is there room for improvement	Action Needed: What should we do next?	Party(ies) Responsible for action	Follow up date?
Value Attribute 1	Mean	8.00				
	SD	1.61				
Value Attribute 2	Mean	5.71				
	SD	1.58				
Value Attribute 3	Mean	7.67				
	SD	1.49				
Value Attribute 4	Mean	5.59				
	SD	1.49				

Figure 3-4 Value fulfillment report – (a) the scorecard summary report showing the mean values of value fulfillment in the different rounds (score check 1, 2, etc.), and (b) scorecard report for filling reflections and actions needed based on one round.

Next step, the project manager inserts the average score (mean value) and the standard deviation (SD) received from the project team into the scorecard. The values will be highlighted in different colors on both sheets. Colors represent the team's stand for the value propositions, and there are three levels for that: recover, improve, and sustain. If the evaluation is high, value is considered achieved during this phase, and the team needs to sustain the results. If the evaluation score is moderate, then the value is not fully achieved yet; therefore, improvement from the team is required until the next evaluation. If the score is low, there is a need to recover by fulfilling the

value proposition. Finally, the management team can agree on the numeric value for each level. In this framework, inserting a value that ranges from 1 to 5 means the value attribute is weakly discussed so far into design or inadequately incorporated into the design; therefore recovery needs to take place; a score in a 6 to 7 range means this attribute has been worked on yet there is still a window for improvement; then range 8-10 indicates that the team has achieved a satisfactory level on the identified value and needs sustainment.

Based on the scores, the team examines the actions needed for items that were scored low and indicated follow-up dates as indicated earlier (Figure 3-4-b).

3.4.4 Step 3- Conducting health checks.

Step 3 entails conducting health checks related to the identified process-related value propositions. The developed survey 2 shall be filled out by the project team monthly to discuss the team members' satisfaction with the practices and behaviors amongst the team. The participants record their agreement with the efficiency of the processes on a scale from 0 – 10, where zero represents complete disagreement and 10 represents strong agreement. For instance, the team indicates the agreement with "we (as a team) have clear, honest and open coordination on the project, and we actively listen to other parties' ideas and concerns". Health checks shall generally include discussions about team motivation, trust among teams, and working towards common goals. Based on the scores received, discussions shall take place to resolve any concerns and act proactively to change any inefficiencies. This health check would help achieve alignment on the team and a higher understanding of the problems that act as setbacks to achieving the best value on projects.

3.4.5 Step 4- Analyzing communication using SNA Modelling

In step 4 of the framework, communication patterns and team dynamics are investigated. This step utilized social network analysis, fuzzy logic, and clustering techniques. What follows will explain

the subsequent management practices needed to complete the SNA visualization and perform the analysis.

First, social networks need to be created to visualize communication patterns, understand connectivity on a project, and evaluate teams' cohesion and integration. Survey 3 helps in obtaining the components of the social network. The project manager must first identify the list of names involved in the current design phase and the individuals expected to communicate about the identified value propositions. The survey includes a matrix where the names are listed on the left-hand side, and participants need to indicate with whom they communicate. They also provide three aspects of their communication: the frequency of communication with the identified person, the most frequent mode of communication with this person, and the importance of this communication to the participant's work. Table 3-1 explains the levels for each of the aspects examined. After receiving the survey results, two networks are built containing the same number of nodes, as they represent the participants, yet different weights for the network edges.

In this research, edges indicate communication is taking place between the network nodes; thus, information exchange is happening between the two connected nodes. The node size is usually associated with a higher number of connections within the network. The first network (N1) is developed based on obtaining the weight from the frequency and mode of communication, while the second network (N2) is built based on assigning the importance of communications between participants as the weight of the edge. The goal for building these distinct networks is to compare the communication that is taking place in the first network to the information flow that needs to exist when important information is present between nodes or teams, as indicated in the second network. The two networks will help managers detect bottlenecks and find the nodes with high control over the network. The comparison will also help answer the following question: are

individuals identified as having critical information to different team members communicating efficiently?

Table 3-1. Survey 3 components

Item	Requirement	Scale/ levels
Frequency	Indicate the frequency of your communication with this person about the project requirements and agreed-on design values	☐ N/A ☐ 1. Minimal ☐ 2. Sometimes ☐ 3. Frequently ☐ 4. Very frequently ☐ 5. always
Mode	Indicate the most frequent mode for design values communication with this person	☐ N/A ☐ 1. Chats/texts on virtual platforms (informal communication) ☐ 2. Emails ☐ 3. Meetings (in-person or virtual)
Importance	In general, indicate the importance of communication with this person for your work.	☐ N/A ☐ 1. Slightly important ☐ 2. Important ☐ 3. Very important ☐ 4. Extremely important ☐ 5. Critical (have discussions that affect decisions on the project).

For N1, the weight is calculated based on quantifying the mode and the frequency of communication. The frequency is 1 – 5 [minimal communication to always communicating], as indicated in Table 3-1. The frequency is relative to each person, meaning that the person will evaluate the frequency of their communication with one team member against the frequency of communicating with another. For instance, a person communicating with someone twice per week considers this a frequent communication as it is sufficient for them, while another person could

say the twice-per-week communication with another team member is considered minimal. Therefore, the authors employed a linguistic scale instead of identifying the number of communications.

For the mode of communication three common modes of communication were identified. They were included in the framework: chats/texts on virtual platforms (informal communication), emails, and meetings (both virtual and in-person/ more formal communication). There might be other common means for communication on different projects, such as phone calls, yet it is important to select the three most common means on the project under investigation and add them to the survey. At this stage, the project manager needs to evaluate which mode of communication is most effective when important information is being exchanged between teams. In the framework, five levels of importance were used: (1) slightly important, (2) important, (3) very important, (4) extremely important, and (5) critical, where this communication affects critical decisions on the project. Team behavior can indicate which mode is most frequently used for the five levels of importance. Different people tend to find different modes of communication more effective than others. While in-person meetings might be the most efficient way for communicating critical information with different teams, others might prefer written communications using email threads or informal chatting. Consequently, a fuzzy membership function can be deployed to identify the common communication method associated with each importance level among the teams on a given project. This helps remove the subjectivity of the evaluation. According to Silva et al. (2014), a degree of imprecision is inherent in human thought processes, which can be captured by fuzzy logic. Unlike traditional logic, which relies on binary true or false evaluations, fuzzy logic allows for degrees of truthfulness, connectedness, and inference rules. This is achieved by measuring the extent to which an object is comprised in a

fuzzy set instead of a crisp set. The use of fuzzy logic is often justified by its ability to handle uncertain input data and convert qualitative variables into quantitative ones (Abreu & Calado, 2017). Figure 3-5 presents the general membership function for communication mode with respect to importance level. The identified membership function needs to be calibrated based on each project communication modes.

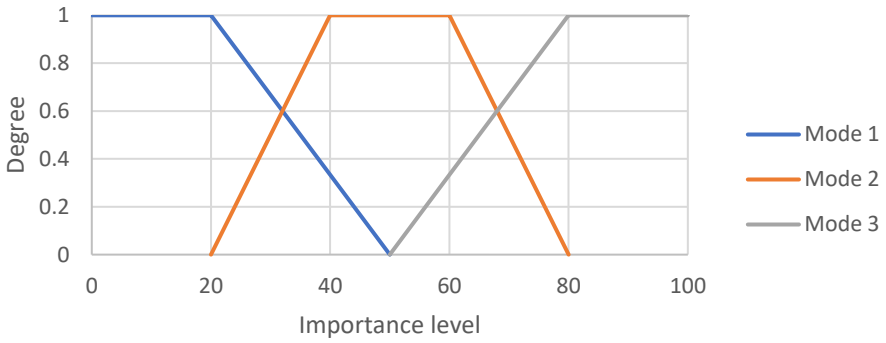


Figure 3-5 General membership function of communication mode

Once the most common mode is identified for each importance level, the weights could be calculated based on equation (1).

$$\text{Weight (N1)} = \text{frequency} \times \text{modified mode} \qquad (1)$$

Frequency values range from 1 to 5, while the modified mode is the conversion of modes relative to one mode based on the importance level. After the calibration of the membership function for different modes, the defuzzified value should be used for modes conversion. For instance, if mode 1 was found to be used two times more than mode 2, and 5 times more than mode 3, for critical importance level, then by assuming the modified mode for mode 1 is ten, then this value for mode 2 will be five and for mode 3, two. This change ensures that all the communications are evaluated using the same scale and based on the collective team behavior.

For N2, the importance factor, which ranges from 1- 5, is used as the weight of the edges connecting the nodes. In this case, the network reveals the vital connections needed for information flow and transferring valuable information among the team members regardless of what is happening on the actual recorded communication level. Hence, network two is considered a technical indicator of information dependency among the team members.

The final step in this phase will be to import the nodes (source and target) and the weights to a network analysis and visualization platform. This research employed Gephi Software for visualizing the networks and collecting the SNA metrics.

3.4.6 Step 5- Identifying correlations, analyzing inter and intra-communications, and performing clustering techniques.

Steps 5 of the framework involves advanced analysis and evaluation based on the three data components prepared so far: (a) value fulfillment report, (b) health-check report, and (c) Social networks N1 and N2 with their metrics. The advanced analysis includes (1) analyzing the graph metrics to check connectivity, (2) comparing the two networks to figure out any possible bottlenecks and compatibility between information dependency and communication dynamics, (3) investigating inter-and intra-teams' performance, and (4) checking for clustering and communities' formulation. The authors also examined in this research which metrics are highly correlated with value fulfillment to help teams assess their practices with respect to value alignment. The correlation is deducted from the case study discussed in the next section.

Every team needs effective communication to succeed. Inter-team and intra-team communication are the two primary forms of communication within a team. Communication between various teams or departments within an organization is called inter-team communication. This type of communication is crucial to ensure that all teams are working toward the same goals and objectives

and that information is shared throughout the organization. Meetings, emails, phone calls, and instant messaging are just a few ways inter-team communication can be carried out. Inter-team communication must be precise, timely, and clear for all teams to collaborate successfully. On the other hand, intra-team communication refers to communication within a team or department. Building strong working relationships between team members and ensuring everyone is on the same page regarding project goals and timelines requires this type of communication. Regular team meetings, one-on-one conversations, daily stand-ups, and team messaging platforms are just a few ways intra-team communication can occur. So that team members can function as a cohesive unit and accomplish their objectives, open, honest, and collaborative intra-team communication is crucial.

Communication within and between teams is crucial for any team to succeed. Teams that prioritize effective and clear communication work together more effectively to accomplish their objectives quickly and with better results.

3.5 APPLICATION: CASE STUDY

3.5.1 Project description

As indicated in the methodology, a case study has been deployed to test and improve the framework presented in this chapter. The project included renovating a historic educational building and integrating it with a newly developed facility on a public university campus in Canada. The main goal of this project is to be a front door and a crossroad for the university community, where the whole community should feel welcomed and have a sense of belonging. The project management team established the guiding principles and building drivers; then, the value attributes were developed per the drivers and programming principles. The total budget for the fit-out phase was estimated at $97,482,375. The project design was estimated to take 12 months

and is taking closer to 28 months. Even though the project delivery method is not an integrated project delivery (IPD), the project still followed a collaborative design approach where the contractor was involved early in the design phase. Lean principles were also part of the team culture where the management team and team members' relationships were based on trust, teamwork, team integration, aligning interests and objectives, and continuous improvement practices. The project had three phases where deficiencies from the first phase were reflected upon and avoided in the following phases.

Five teams were involved in the design meetings and design decisions and were thus invited to participate in this study. The teams were from the owner's side the project management team and the leadership team, the consultant team, builders' team, and the campus-planning and space optimization team. Other stakeholders such as the end-users were represented by two cross-institutional committees, the executive oversight committee and the project steering committee.

3.5.2 Value identification

The project had early briefing exercises conducted to identify the guiding principles by the university standards. Then, based on the identified project goals and guiding principles, a survey was conducted to collect perspectives on what is essential for the success of the project, what is desired, and what items might seem not desirable. One of the authors worked with the project manager to formulate the survey. The survey included the six guiding principles that needed to be translated into value attributes; these were: sustainability and well-being, integrating existing and future development, community, social achievement and retention, inclusive design principles, adaptable, flexible, and efficient spaces, equity, diversity, and inclusion (EDI), and indigenous initiatives. These guiding principles were basis for developing the core and shell value attributes, and discussions were made to specify exactly the elements that help in achieving these principles.

The survey was then conducted to prioritize these elements. The final list was developed and tracking the items on the list was performed through value fulfillment report and the monthly health-check reports.

3.5.3 Value Fulfillment report & Health-check report

The team sporadically reported the percentage fulfillment of the value attributes based on the project design progression. This served as a reminder for all teams involved in design about the value attributes that need to be achieved by the design and construction team. Monthly health-checks were conducted. The authors collected four value fulfillment reports during the year of their observation and nine health-check logs. Results are reported in Figures 3-6 and 3-7.

The value fulfillment report revealed that during round 1, 12 out of 14 identified value attributes needed recovery and improvement where the mean score was below 8 out of 10. In later phases, and with the addition of one value attribute to the list from the added-value items, 6 out of 15 items needed recovery and improvement. This means that the team had successfully increased attention to value alignment and attainment during the development of the design.

Core Value Attributes		Score Check 1	Score Check 2	Score Check 3	Score Check 4
	Date	MAY_2022	June_2022	July/Aug_2022	Nov/Dec_2022
Academic programming requirements are supported		8.00	8.71	8.60	8.47
Food service		5.71	7.00	4.86	6.29
Bookable meeting spaces		7.67	8.18	8.13	7.95
Indigenous recognition		5.59	**4.38**	**4.60**	5.91
Lounge space and wellbeing		7.37	8.07	7.57	7.79
Acoustics and Daylight views (Right to Light)		8.11	8.64	8.45	8.69
Flexibility for future expansion		7.32	8.27	8.08	8.20
Durable material selection/ low operational & maintenance requirements		7.61	7.93	7.80	8.47
Simple, effective & efficient technology selection for good performance		7.72	8.31	7.46	8.68
Indoor Safety (slip, fall)		7.63	8.55	8.67	8.93
Security (Video cameras, access system, etc.		7.20	7.25	8.00	8.27
Overall cost reduction and competitive prices		7.47	7.56	7.50	8.50
Barrier-free access and signage		7.82	8.50	8.88	8.63
Exhibit Space		6.31	7.20	6.00	7.23
Interactive AV/Digital wayfinding		0	0.00	5.67	7.30
AVERAGE VALUE FOR VALUE LIST		7.25	7.24	7.35	7.95

Figure 3-6 Value fulfillment report for the University project

Health check Log

	1	2	3- SNA	4	5- SNA	6	7	8	9- SNA
Month	March	April	May	June	July/ Aug	Sept.	Oct	Nov	Dec
No. of participants	13	12	14	16	13	17-19	13	16	17
Item									
1. Coordination, collaboration & transparency	8.2	8.1	7.7	7.9	6.9	7.4	7.5	8.1	7.9
2. Proper risk assessment & management	8.2	7.6	6.8	7.5	7	7.6	7.1	7.8	7.4
3. Produce quality drawings for tender & construction	6.8	7.1	6.8	6.4	5.7	7	7.1	7.6	7.5
4. Effeciently utilizing project tools	7.4	6.9	6.7	7.3	6.9	7.1	6.8	7.3	7.3
5. Enjoy going to work with the project team	8.2	8.2	7.9	7.9	7.8	7.9	7.9	8.6	8.1
6. Trusting our fellow team members, no blame culture and mainting harmony between project stakeholders	8.2	8.3	8.2	7.9	7.6	8	7.8	7.9	7.8
7. Respect for eveyone's time commitments	7.8	7.4	7.6	6.9	7.2	7	6.8	7.5	7.2
8. Up-to-date forecasting of design and project schedules	7	6.8	5.9	6.1	6.2	5.9	5.8	6.8	6.1
9. Innovative approaches for time or money savings	6.8	7.5	6.4	6.9	6.9	6.7	7	7.2	6.8
10. Re-work avoidance, in both design and construction	6.4	6.9	7.1	6.5	6.8	6.6	6.8	6.6	6.4
11. Safe workplace & incident-free environment	8.4	8.7	8.4	8.4	8.5	8.2	8.4	8.8	8.1

Figure 3-7 Health-check average scores recorded monthly.

Health-checks log was collected based on survey 2. Participants constantly recorded their evaluation of the practices conducted through the design process. The project manager used to share a Menti-meter link during the design coordination meeting where participants could score the 11-agreed upon process value attributes. Direct reflection and discussions could take place after recording the mean score. For this research, charts were also representative when comparing the performance based on the SNA results. Since the SNA networks were developed during the months of May, July, and December, the results from the health-checks during these months were highlighted as shown in Figure 3-7 for the sake of the analysis. Figure 3-8 illustrates the changes of three value attributes over the course of the design (coordination, collaboration and transparency, enjoy working with the project team, and trusting our fellow team members with no blame culture).

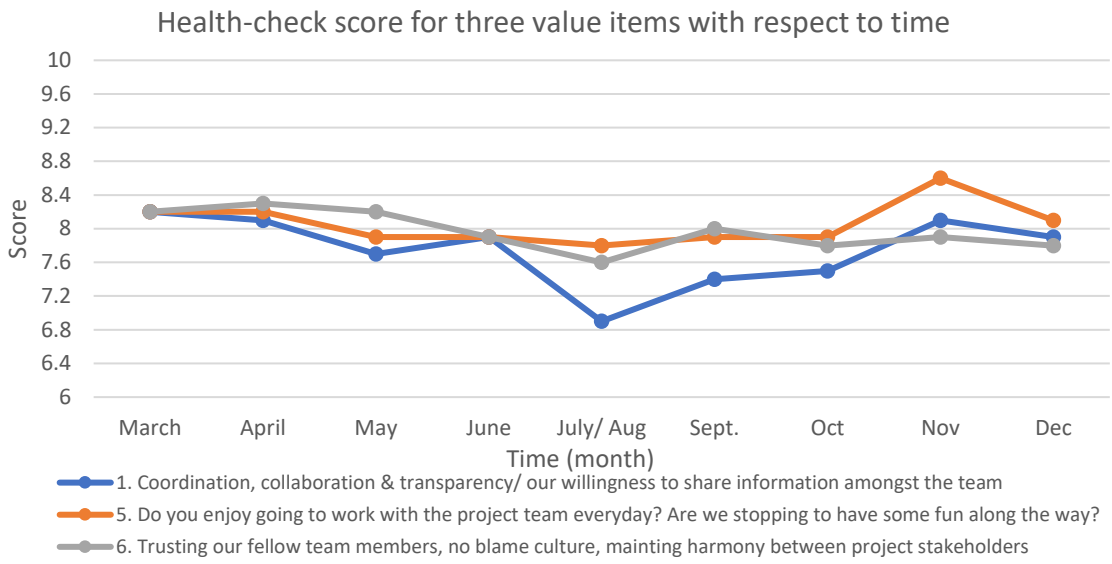


Figure 3-8 health-check plots for three process-value items

Figure 3-8 reveals a recorded drop in coordination and collaboration during the months of July and August. The authors then compared the results with the SNA metrics, and it showed a similar trend. Further analysis is presented in the next section.

3.5.4 SNA visualization and Metrics

As indicated in the framework, two networks for each round were developed. N1 was established based on the frequency and modified mode factors (based on fuzzy – check Figure 3-9), while N2 was developed based on the recorded importance level of the communication between each two members. N1 and N2 are directed networks, meaning that someone could identify the importance of communication with person A as highly important, yet person A could indicate that the information needed from this person is slightly important to their work. Similarly, a person could indicate that they frequently communicate with person B, yet person B indicates that their communication with this person is less frequent. This is normal where the frequency of communicating with someone is relative to the overall communication a person conducts with the project teams. The developed social networks N1 and N2 for round 1 are visualized in Figures 3-

10 and 3-11, respectively. Similar graphs were developed for rounds 2 and 3. The metrics were computed from all six networks on Gephi and are recorded in Table 3-2.

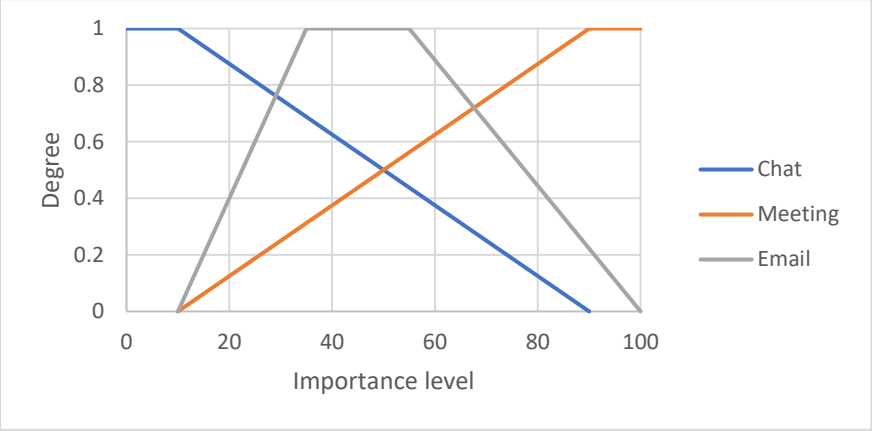


Figure 3-9 Membership function of communication mode

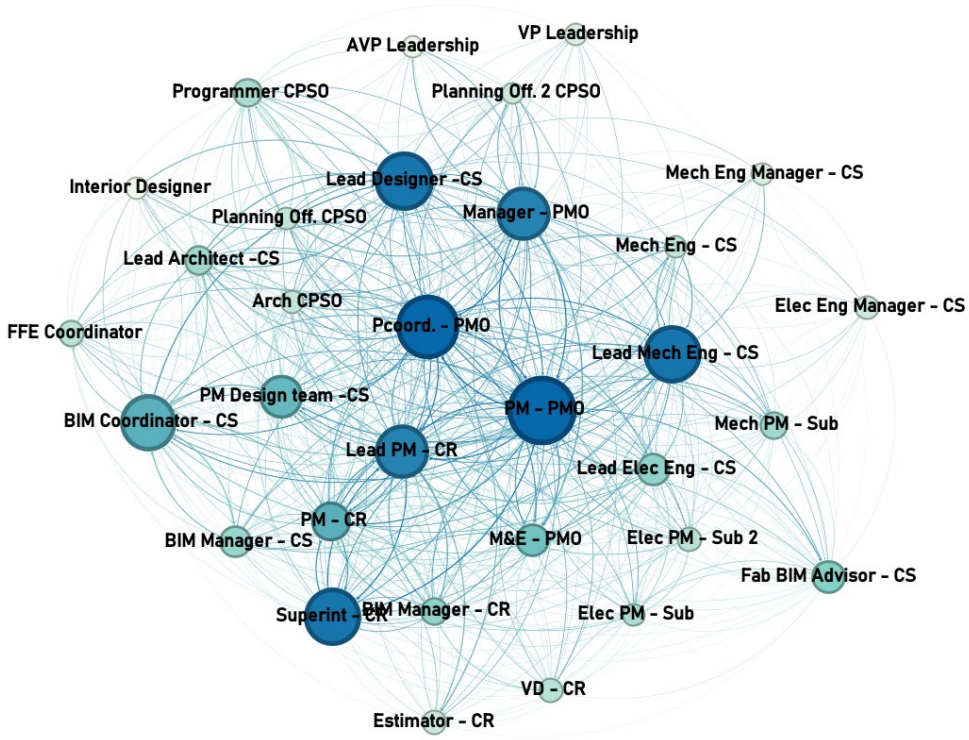


Figure 3-10 Social Network N1 -Round 1 displaying the connections based on frequency and mode.

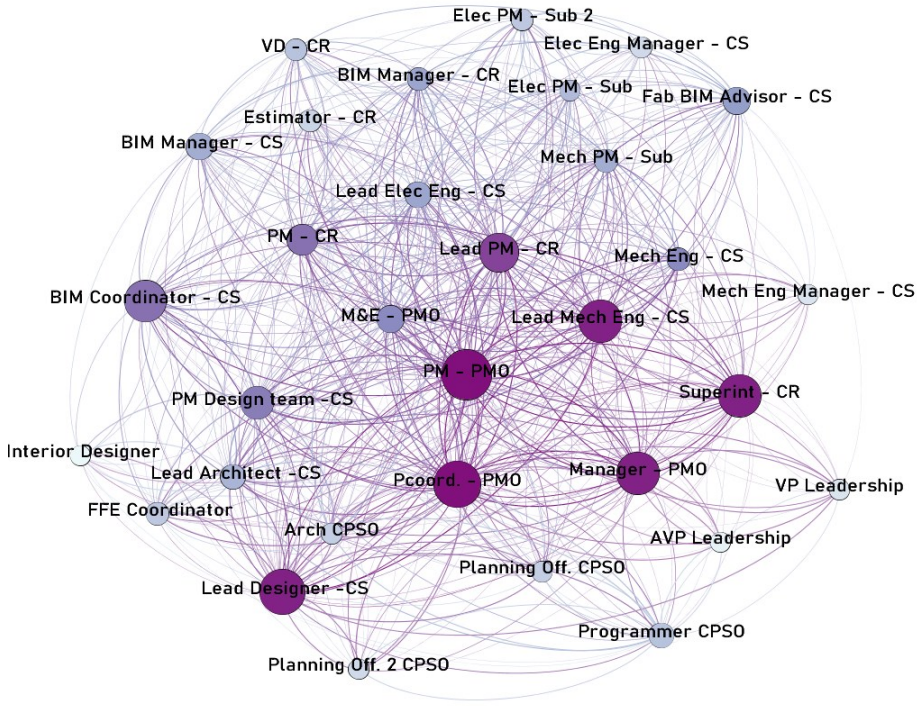


Figure 3-11 Social Network N2- Round 1 demonstrating the connections based on the importance level of information exchange.

Five teams were involved in the design: the consultant team (CS), the project management team (PMO), the leadership team representing high level University personnel (leadership), the contractors or builders' team (CR) including the subcontractors (Sub), and the CPSO team which is the campus planning and space optimization team. The names of participants were replaced in the networks with their roles. The networks reveal visually the team members who are highly engaged with other people on the project. The node size in this case reflects whether the person is highly connected to others or not. The bigger the size of the node, the higher the influence of this individual over the network, as more communication channels are going through them. The PMO team, the Project manager from the contractor's side, and the lead designer from consultants' team were found to be highly communicating with others in the network (Figure 3-10). The same

nodes/parties were found to have important information to share with others in the team based on N2 (Figure 3-11). This reveals a good status of design communication among the team.

Table 3-2. Networks N1 and N2 metrics for the different rounds

Metric	**Network**	**Values in each round**		
		Round 1 32 nodes 613 edges	**Round 2** 25 nodes 378 edges	**Round 3** 33 nodes 712 edges
Average Degree	N1	19.156	15.120	21.576
	N2	19.594	15.040	21.606
Graph density	N1	0.618	0.63	0.674
	N2	0.632	0.627	0.675
Av. Clustering coefficient	N1	0.777	0.82	0.81
	N2	0.778	0.82	0.812
Av. Path length	N1	1.382	1.37	1.327
	N2	1.37	1.37	1.326
Modularity (community detection)	N1	0.127 (3)	0.129 (3)	0.118 (3)
	N2	0.115 (2)	0.058 (3)	0.092 (2)
Av. Betweenness centrality	N1	11.844	8.88	10.485
	N2	11.5	8.96	10.455
Av. Closeness centrality	N1	0.747	0.756	0.777
	N2	0.752	0.754	0.778

The number of people involved in the design varied from round to round. This is reflected by the different number of nodes (representing participants) in different rounds. In round 1, the team needed input from the leadership team and the CPSO team. In round 2, these teams were less involved as their major part was during the initial phases of design. In round 3, the number of participants increased again (33 nodes), revealing that more parties were getting on board in the design. These new participants were mainly from the contractor's team. Both graph density and average closeness centrality metrics had lowest scores in round 1 and highest in round 3, indicating increase in the network connectedness and integration. Other SNA metrics revealed a different trend. Clustering technique was utilized to check for the communities formed within the network.

Figure 3-12 reveals that 3 communities were detected. The project manager found the results interesting as it reveals that some of the consultants' team worked in their bubble. The network gave insights on teams working together and those in silos. It also reflected the fact that the project is not a fully IPD project, and such results are expected during different phases of design.

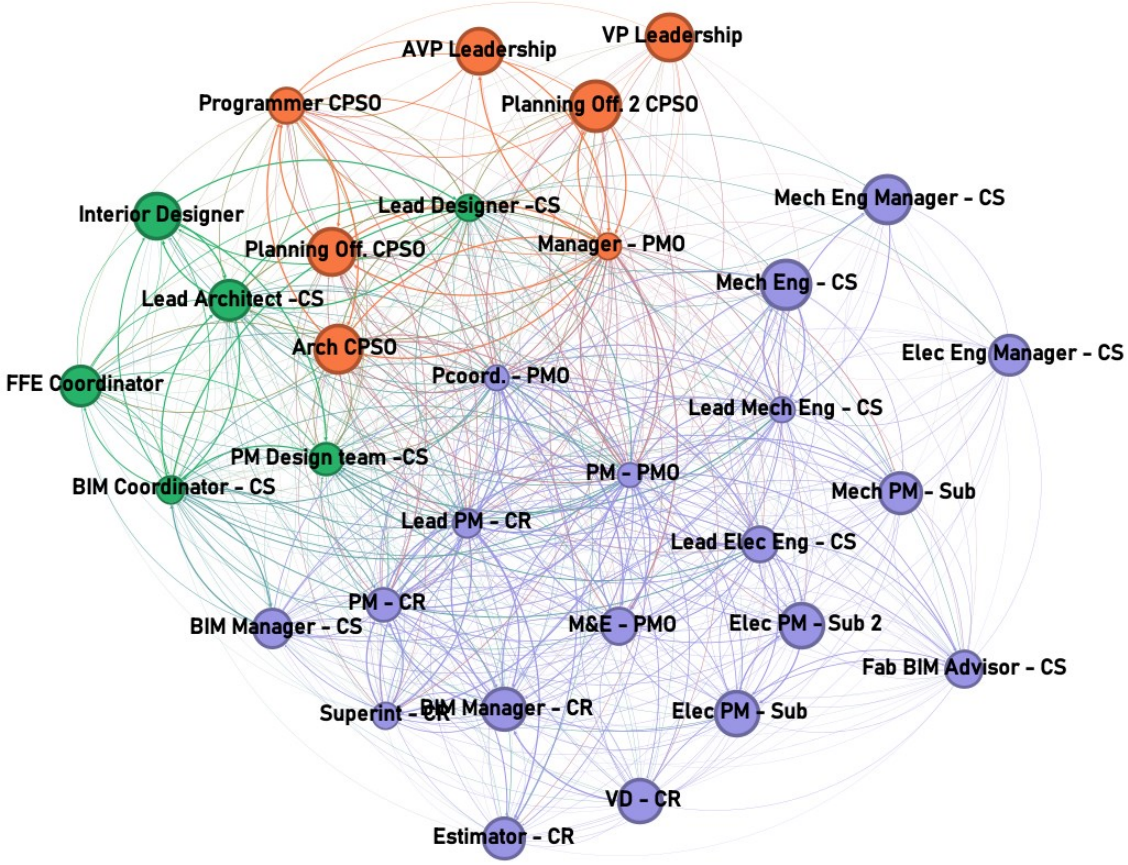


Figure 3-12 Social Network based on clustering- Round 1

3.5.5 Correlation: SNA and value fulfillment and inter-intra teams' relationship

Part of the research objectives is to find possible correlations between team dynamics and reported level for project value. Using the case study, correlations were checked for; Table 3-3 provides the correlation values for different social network analysis (SNA) metrics and Value fulfillment of Network 1 and Network 2. The first metric in the table is Betweenness Centrality, which measures the importance of a node in a network. The table shows that the correlation values for this metric

are negative for both networks, with Network 1 having a slightly stronger negative correlation than Network 2. This suggests that they have a weak negative correlation with value fulfillment.

Table 3-3 Correlation analysis between value fulfillment and SNA Metrics

Correlation	Betweenness Centrality	Closeness Centrality	Avg. Degree	Graph Density	Avg. Clustering Coefficient	Av. Path length
Network 1	-0.24	1.00	0.58	1.00	0.56	-1.00
Network 2	-0.19	0.97	0.51	0.93	0.59	-0.94

A negative correlation means that as one variable's value increases, the other variable's value decreases. In this case, a correlation of -0.24 and -0.1 suggests a slight tendency for the values of the two variables to move in opposite directions, but the relationship is not very strong. The next metric is Closeness Centrality, which measures how close a node is to all other nodes in the network. The correlation values for this metric are positive and close to one for both networks, indicating a perfect positive correlation. This means that when one variable increases, the other also increases proportionally. In other words, the two variables move in perfect sync. Graph Density, which measures the proportion of possible connections between nodes that actually exist in the network, shows strong positive correlation with value fulfillment with values close to 1. This means that when one variable increases, the other also increases. Finally, the table shows the correlation values for Average Path Length, which is the average distance between nodes in the network. It has a perfect negative correlation with value fulfillment. This indicates that the two variables move in opposing directions, with a perfectly linear relationship between an increase in one variable and a corresponding decline in the other. The closer the correlation coefficient is to -1, the stronger the negative correlation between the two variables. When predicting future results or figuring out the underlying patterns in a dataset, a correlation coefficient of 1 and -1 indicates a very close connection between the variables.

For the intra-team communication analysis, Figure 3-13 reports the average communication weight within different teams for three rounds. The communication weight refers to the frequency multiplied by the modified mode within each team during the given round. The figure presents data for three teams, namely Builders Team, Consultant Team, and PMO Team, and for three rounds, namely Round 1, Round 2, and Round 3. It shows that the Builders Team had a lower average communication weight in Round 2, with a value of 156, which significantly increased to 217 in Round 3. On the other hand, the Consultant Team had a stable average communication weight in all three rounds, with a value of 166 in Round 1, 181 in Round 2, and 197 in Round 3. The PMO Team had the lowest communication weight in all three rounds, with values of 129 in Round 110 in Round 2, and 125 in Round 3. The data could be useful in identifying which teams were communicating the most and which were communicating the least during the project. This information could be useful in improving team communication and identifying areas to be improved in future projects.

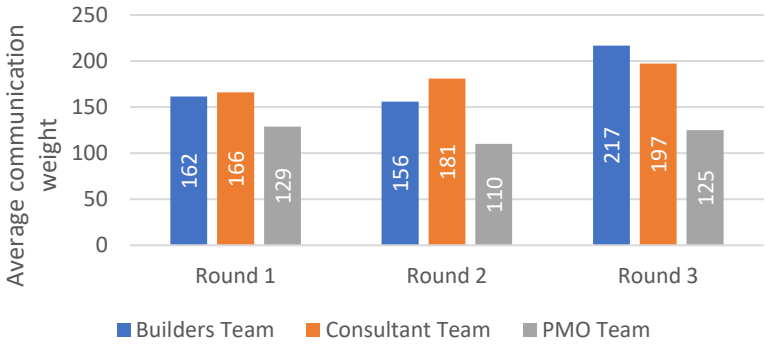
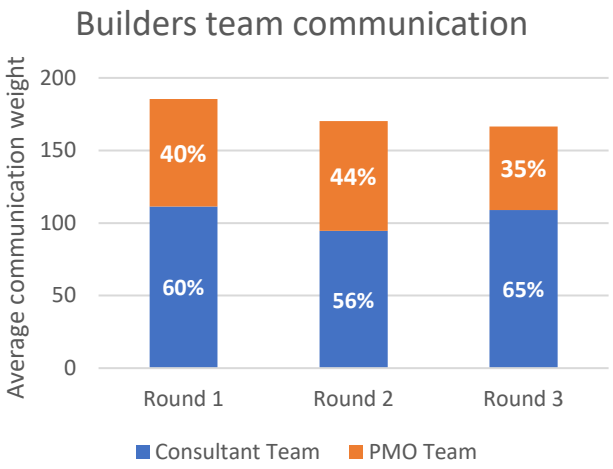
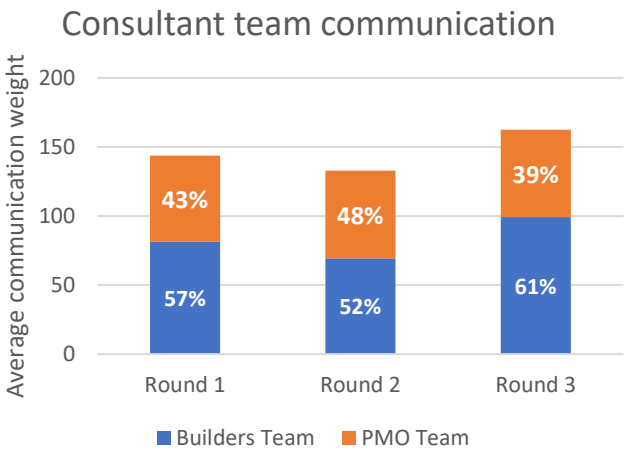


Figure 3-13 Intra-team communication

The three charts provided in Figure 3-14 show the average communication weight between three teams across three rounds. In the first round, the Builders team had the highest average communication weight with the Consultant team compared to the PMO team. Analyzing the

communication weight of the Consultant team, it is evident that in all rounds, they had a higher average communication weight with the Builders team compared to the PMO team. However, it's worth noting that the communication weight of the Consultant team with the Builders team decreased from round 1 to round 2 before increasing again in round 3. Conversely, the communication weight of the Consultant team with the PMO team remained relatively consistent across all three rounds. Looking at the communication weight of the PMO team, it is clear that they had the highest average communication weight with the consultant team in round 1, while their communication weight with the builder team was the highest in round 3. However, the communication weight of the PMO team decreased with both the Builders and Consultant teams in round 2 compared to round 1. Overall, while the provided tables give some insight into the communication dynamics between the Builders, Consultant, and PMO teams, without additional context, it's difficult to draw any definitive conclusions. The results were thus discussed with the project manager and compared to the health-check trend in different rounds to figure ways for improvement. Understanding the purpose of the communication, the specific topics discussed, and the overall project goals would be helpful in fully interpreting the findings. Moreover, comparing the trends and patterns in the communication weights across all three teams could identify areas of strengths or weaknesses in the communication process.





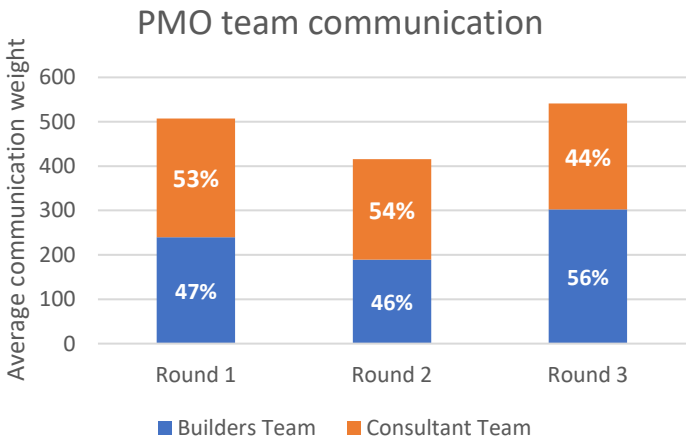


Figure 3-14 Inter-team communication

3.5.6 Framework validation

As part of the validation, the authors asked industry experts about the effectiveness, applicability, and feasibility of the framework. The experts were part of the project presented in the case study. Overall, they strongly agreed that the proposed framework is effective and takes away part of the subjectivity, has the right sequence of implementation, and is applicable to other projects.

3.6 DISCUSSION

The case study demonstrated how teams evolve on projects, how their communication pattern changes, and how attaining value for the project is a continuous and dynamic process that needs

follow up. The presented framework helped in tracking teams' communication during the design development phase to check whether the value attributes agreed-upon are translated into design. Social network analysis helped in identifying communication bottlenecks, the parties controlling the project, and the communities that are being indirectly formed across teams. Results also revealed that SNA metrics may be a good indication of how the project is doing in terms of value conversations and attainment. In other words, the case study revealed high closeness centrality and low average path length values in round 3 which indicated a well-connected network that yielded higher average value fulfillment and high scores in the health-check report. This proved that higher communication and connectedness in the social network shall yield better alignment in value propositions, and higher preparedness to attain those value attributes. The framework also identified the most common modes of communication in the project which were chats/texts, emails, and meetings. Meetings were found to be the most effective when important information is shared. Note that 3D models and BIM were also shared during meetings to better coordinate design and translate the value attributes into these information models.

In general, the framework can be used by project managers as a tool to understand and visualize team communication and interactions, to track how teams are doing in terms of fulfilling the process and product value attributes, and to take corrective measures to improve both communication and value fulfillment. The research provides evidence that there is a pressing need for thinking about the design process of any project from a wider social perspective. We need projects with impacts internally and externally. Internal impact means everyone involved in the design and construction processes understand the bigger picture of the project, in other words they understand the requirements not just of their own discipline but also those of their fellow team members, then work together towards these goals that are identified as a set of value attributes.

External impact translates into the needs of every party impacted by the project and is not necessarily available during the development process. The project should be built to satisfy at least their bare minimum rights to conclude a successful project. These parties consist of, not only the users of the project, but also the surrounding community and neighborhood that are usually indirectly impacted by projects, specifically public projects. When designers and developers consider communities' needs, we start talking about inclusive design in the built environment that considers equitable living for all members of the community. This whole idea cannot be achieved without building a strong network of people who trust each other, share ideas, and evaluate design and construction regularly based on the value list developed with combined effort.

Managing stakeholder relationships and their interaction is the main enabler for delivering higher value on projects. In return, to better manage teams and stakeholders, communication is an asset. Poor communication and communication breakdowns lead to setbacks on projects. Prevention can be done through analyzing the socio-technical performance on projects through the proposed framework. The framework can help industry identify, measure, and align value while studying communication within design teams and among other stakeholders. In this sense, the presented framework encourages the implementation of the initial step of value identification to be able to implement this framework. Hence, value generation would commence as soon as discussions are commenced regarding what is of value for this project, as part of the value identification process. The application of the framework needs additional consideration to lean practices which would help in achieving the intended outcome. Having a big room meeting monthly or by-monthly for teams to co-exist in one location is important. Additionally, lean philosophy calls for building a culture that supports teamwork and communication which is in line with this framework. To identify and improve value on projects as per the lean guidelines, teams

need to bring problems and conflicting requirements to surface, have candid conversations, and proactively manage these conflicting requirements to avoid rework (Tillmann 2018). Global optimization is needed across teams rather than solo works and local optimization. To this end, this framework needs to be associated with a lean culture that needs to be established among the team involved on a project to be able to reap the full benefits of implementing it.

3.7 CONCLUSION

Design management practices have been relying on technical performance indicators on projects with little attention to the social aspects of projects, specifically in the era of digital technologies. Lean design management calls for increasing value delivery on projects to satisfy an extended list of stakeholders. Human and social needs should be part of the design and production processes, yet dealing with these needs is a stumbling block when not dealt with in a structured manner. The research presents a socio-technical approach and a lean management framework to analyze team dynamics by examining communication patterns on projects and connecting it to value alignment and fulfillment. Studying human interaction in design is deemed essential for improving the architecture and engineering design management practices as envisioned in the Industry 5.0 paradigm. Therefore, this research presented evidence that team structure and communication affect value alignment on projects and subsequently value attainment by deploying social network analysis and correlation techniques. Results revealed that even when an integrated project delivery approach is not feasible on a project, collaborative practices could still be accomplished, and team alignment could be achieved by increasing communication and connectedness among the team, and through a lean culture. The research thus provides insights on how to ignite the human-centricity during design by focusing on both the design process through health-checks and on the design outcome through the product value propositions.

3.8 ACKNOWLEDGEMENT

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Chapter 4: Employing Simulation to Assess Value Alignment and Fulfillment within Construction Project Settings and Team Dynamics

Value-based management has been gaining momentum in the Project Management field. Effectively managing value, and any competing objectives, is in fact crucial for achieving successful projects. To do so, project settings and team interactions need to be investigated as they have a major influence on delivering value and aligning stakeholders' perceptions. Therefore, to understand how these influencing factors affect value, this chapter introduces the development of a simulation model as a tool to help project managers investigate value alignment and fulfillment within the unique context of project settings and team dynamics. The agent-based simulation tool models the interactions between teams and their effect on emergent behavior with respect to value adoption. By inputting relevant data and configuring different parameters, results from the applied case study showed that the simulation tool can provide insights on value fulfillment levels. This would inform managers in making value-centric decisions and adopting effective approaches for planning and managing value on their projects.

4.1 INTRODUCTION

In the complex and dynamic world of construction projects, there has been an emergent uptake of value management practices to deliver the best value and benefits for clients, users, and other stakeholders (Kelly et al., 2004). Stakeholders, including project managers and project teams of designers and contractors, interact to create and deliver value (Pirozzi, 2017). Thus, managing the relationship with and among project stakeholders is central to soliciting their requirements and embedding their needs into project design and construction (Tillmann, 2018). There exists

numerous definitions for construction value management, yet they all share these common fundamental components: being team oriented, entailing the explicit identification of the clients' value system, driven by functionality, having proactive and creative endeavors, and finding application at various stages of project development (Kelly et al., 2004). Given these components, value management is a continuous process that goes beyond value workshops conducted during the early project phases (Emmitt et al., 2005). The literature has offered extensive material for these workshops, yet the continuous tracking and assessment of value alignment and fulfillment lacks reliable tools. The absence of these tools can be attributed to various factors. First, subjectivity plays a significant role in stakeholders' perception and interpretation of project value as it reflects their individual priorities, experiences, and interests in the project (Thyssen et al., 2010). Although early workshops help foster a mutual and shared understanding of project goals, the lack of involvement of various stakeholders during the later stages of design, when required, can impede the progress achieved. Second, assessing social aspects of projects that shape project value and influence its outcomes becomes challenging without adequate tools and indicators. Lastly, besides gathering teams' feedback on their perceived level of achievement regarding projects' requirements, no direct measures are available to assess value fulfillment (Giménez et al., 2020).

Moreover, the Institution of Civil Engineers (ICE) identified three key subprocesses for value management: value planning, value engineering, and value reviewing (Kelly et al., 2004). While value engineering is well known and sought after on projects, value planning remains relatively underutilized, often limited to superficial workshop exercises. In describing an enhanced value study process, Kelly et al. (2007) offered better guidance on the diagnostic and planning phase to identify value context. They highlighted the importance of understanding the strategic

context of the value study by figuring out its scope, timing, schedule, and constraints. This process also hinges upon securing commitments from stakeholders (Kelly, 2003). Additionally, value reviewing is hardly discussed within the existing literature and its practical implementation remains limited.

Another critical issue when discussing value on projects is alignment. Decisions on projects would require alignment among stakeholders. By definition, alignment is "the condition where appropriate project participants are working within acceptable tolerances to develop and meet a uniformly defined and understood set of project objectives" (Griffith & Gibson Jr, 2001). The reality, however, is that different teams perceive the project value differently, and there is more often than not misalignment between the paying client and other stakeholders on projects (Drevland et al., 2017).

While there is no single, universally agreed-upon metric to measure value, understanding and incorporating the diverse viewpoints of various stakeholders to create a fully integrated list of project value propositions is needed as a first step to achieving effective management (Khalife et al., 2022). Open communication and discussions about value fulfillment and having tools to help assess the influence of different factors on the project and their impact on value will help bridge the gap between stakeholders' subjectivity and the objective project goals, leading to a well-balanced assessment of project value components.

Additionally, organizational networks have a critical role in successfully delivering projects; Studies have stressed on the need to integrate communication and knowledge exchange, highlighting the need to achieve the right balance in communication (Chinowsky et al., 2011). Effective project communication networks heavily rely on inter- and intra- organizational communication. These forms of communication are crucial for fostering a learning environment

within the project and enhancing the ultimate project value (Emmitt et al., 2005). Building on this point, social dynamics on projects and the effect of team interactions add to the complexity of value fulfillment. Effective team interactions foster a positive work environment where members feel comfortable expressing their ideas and opinions. This open and inclusive atmosphere encourages creativity, promotes knowledge exchange, and allows for the exploration of various design possibilities and maximizing value generation (Whelton et al., 2003). By studying these interactions, project stakeholders gain valuable insights into the team dynamics, identifying strengths and areas that require attention or development. Under stakeholders' management, the power-interest grid is usually utilized to analyze stakeholders' influence and how to deal with them (Olander & Landin, 2005). Nonetheless, an integrated understanding of stakeholders' influence, their dynamics, and communication network is still needed. Simulation techniques have proven effective in studying factors influencing systems in construction projects (AbouRizk, 2010). Simulations allow project managers to model different scenarios and test variables to identify the most effective approaches needed. Agent-based modeling has gained attention given its ability to showcase and analyze complex interactions and human behavior in businesses and on projects and support decision-making (Macal, 2016). In value research specifically, it has been used by several authors to model the effect of stakeholder interactions on value in different project types and from different angles (Stephan & Menassa, 2015). Yet, none of these studies explored the fulfillment of value based on factors related to both planning the value propositions discussions and the teams' interaction and effective communication.

Effective management of these critical factors can make a huge difference between the success and failure of projects. This research delves into the relationship between team dynamics, project setting, and value delivery, aiming to provide a practical tool for improving projects

outcome in terms of value delivery. The main objective is to monitor value fulfillment and alignment by modelling the interconnectedness between team characteristics and dynamics, project features, and value propositions. By understanding the nuances of team behavior and communication and by leveraging the unique characteristics of each project setting, managers can unlock the true potential of their team's endeavors, achieving enhanced value of projects. This involves tracking performance against predefined targets, and taking necessary corrective actions as needed. Regular review and evaluation of value management initiatives help to continuously optimize value and make informed decisions.

By deploying simulations as a value management tool, project managers can continuously monitor value alignment and fulfillment throughout the project lifecycle. They can compare simulated results against predefined value metrics and milestones, allowing for early detection of deviations and the implementation of corrective measures. This proactive approach empowers project managers to keep projects on track, align team efforts, and ensure the project's value objectives are met or exceeded.

4.2 RESEARCH METHODOLOGY AND METHODS

The research methodology used in this research is design science research (DSR). The DSR methodology consists of six activities or steps and are implemented in this research as follows: (1) the authors identified the problem and stated the motivation for the research, as detailed in the previous section, (2) defined the research objectives as building a simulation tool that helps monitor value fulfillment and alignment by modelling the interconnectedness between team dynamics and project features, (3) designed and developed the management tool (the artifact) as a potential solution for the identified problem, (4) demonstrated the use of the artifact in a case study, (usually the demonstration step could involve experimentation, simulation, or case study), (5)

performed evaluation through comparing the observed results from the tool to actual results from the case study and evaluated if this meets the objectives stated (usually this step could include quantifiable measures, empirical evidence, or logical proof), and lastly, (6) communicated the problem and its importance in addition to the artifact, its utility, and novelty through this research (Peffers et al., 2007). Figure 4-1 reveals the DSR methodology steps implanted in this study and the associated details and methods under each step. The design and development step includes building the conceptual model and the computational model, with the mathematical model and case study serving as the demonstration step. The subsequent sections will delve into discussing the model, the results obtained, and model validation and verification sections.

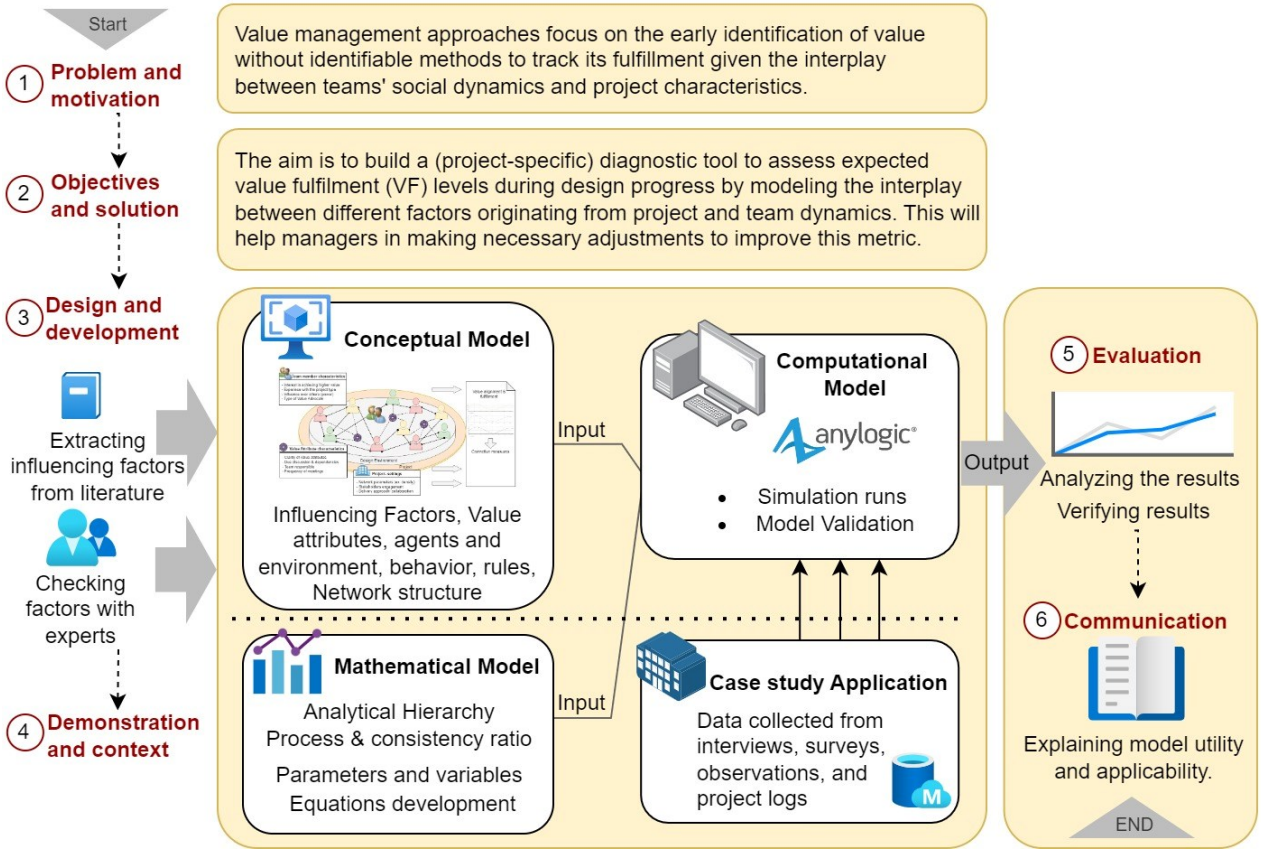


Figure 4-1 Research methodology steps and details

4.2.1 Model rational, design, and development

This research focuses on the effect of interactions, teams' characteristics, and specific project settings on value fulfillment and alignment. When dealing with dynamic social aspects and team behavior, simulation modelling techniques are considered powerful tools for simulating different scenarios, generating valuable projections and forecasts, and understanding the complexities of a system (Happach & Tilebein, 2015). Simulations allow project managers to test different strategies that impact project outcomes. Agent-based modelling specifically allows for depicting the emergent behavior of agents or teams within a particular setting (Macal, 2016). Given these factors, this research adopted agent-based modeling to present a tool that can model interactions, navigate the complexities of team dynamics, and capture the team's behavior within the project setting. The agent-based modeling simulation is developed to allow managers to model different scenarios and assess the impact of their planning strategies and the impact of project team dynamics on value fulfillment. As a result, the agent-based modeling technique will help in:

- Testing the emergent behavior resulting from team interaction
- Representing social network structures where agents interact (explicit connections)
- Capturing how the behavior of individuals shapes the overall system.

The first step before designing the model was to specify the factors that need to be included in the simulation. Note that simulation models are abstractions of the real system designed to mimic the behavior of the system. These models are usually reductive as modeling complex interconnected variables within the system can complicate the process and results in a computationally intensive model. Therefore, calls for simplified models to meet objectives are recorded in literature (Stewart Robinson, 2014). Also, simulation models can be minimalist models where most important factors are included to make the model's structure and behavior more

interpretable and easier to communicate to stakeholders (Macal & North, 2005). Excessive complexity can hinder comprehension and make drawing meaningful insights from the simulation results harder, nonetheless, oversimplification leads to insufficiently accurate models (Stewart Robinson, 2022). Accordingly, after extracting factors affecting value alignment and management from the literature, a careful understanding of the factors was performed with experts' validation to provide a meaningful model and aim for accurate insights. The selected factors are discussed in the simulation model section.

Having selected the critical aspects that drive the outcomes of value fulfillment and having one of the authors closely observing teams during value alignment sessions over the period of one year, a conceptual model was developed, including the factors, attributes, agents, their behavior, and the environment within which these agents are interacting.

A case study was deployed for quantifying and developing the mathematical model, including factors weighing in the generic model. It is important to mention that the weights are case-dependent. When discussing this application with experts, they agreed that factors possess varying weights across different projects, depending on the project dynamics and delivery approach. Note that multiple methods for factors weighing can be employed, and they remain acceptable as long as they accurately represent the project managers' desired reflection of the reality of their projects. These methods should demonstrate which factors truly exert a greater impact on the final outcome and quantify the extent of their influence.

The results of the conceptual and mathematical models are fed as inputs into the computational model. The computational model was developed using AnyLogic, a simulation modelling software, that is used by companies and researchers worldwide. The design process of

the AnyLogic model was conducted iteratively, involving the validation of the model's logic by experts who have significant experience in optimizing project value.

4.2.2 Validation and demonstration through a case study and data acquisition

After developing the computational model in AnyLogic, a case study was selected to validate the model's application. The case study provided a real-world context that closely resembled the system we aimed to model. This allowed us to capture the relevant dynamics and interactions among different agents within the system accurately. In previous research, the authors employed social network analysis in the same case study to visualize and assess the design communications among teams. This study utilizes these communication patterns to understand the interaction dynamics. Furthermore, the selected case study encompassed various factors and elements crucial to the research objectives. The authors had access to the project data and met several times with the project manager to validate the model's rationale. Finally, the value fulfillment and alignment results were used to validate and calibrate the model, which ensured that the agent-based model accurately reflects the observed behavior of the real system.

4.3 THE SIMULATION MODEL: A DIAGNOSTIC MANAGEMENT TOOL TO MONITOR VALUE ALIGNMENT AND FULFILLMENT

This section describes the model details starting with the conceptual model and its components: the factors modeled, the agents and their characteristics, the agents' interactions, and the environment within which these interactions occur. Additionally, the mathematical model is presented to guide model users on identifying model variables and assigning weights to different factors. The computational model is then explained, followed by the case study to demonstrate model applicability.

4.3.1 Model objectives

The initial phase of any simulation modelling process involves understanding the problem, identifying the model objectives, and determining the researchers' goals for this model. Robinson (2008) explained that simulation studies have two objectives: modeling objectives and general project objectives. These objectives are considered part of the conceptual modelling process that would help identify the experimental factors or model inputs (S Robinson, 2008). In this research, the authors aim to help project managers investigate the effect of project characteristics and other factors on shaping value propositions fulfillment. This is the overall aim of the research. The model, however, could contribute towards this goal by determining the expected duration for fulfilling value propositions as design progresses. Therefore, the specific model objectives are:

> *To build a (project-specific) diagnostic tool to track value alignment and calculate the expected estimated time needed to fulfill project value. The model will help project managers understand the interplay between different factors originating from project and team dynamics and their effect on value. Managers could then decide whether they are doing well regarding value fulfillment on projects or need to make adjustments to improve.*

For the project objectives, these might include the following considerations: flexibility, run-speed, visual display, and/or ease-of-use and reuse (S Robinson, 2008). For this project, the objectives are to have (a) good flexibility where the model could be adjusted or customized by other modelers – if necessary, (b) ease-of-use where project managers can update the info in an Excel sheet which is connected to the model, and (c) model reuse, where this could be used on different projects and even reused and updated in different phases on the same project.

4.3.2 Conceptual model and modeled factors

Based on the specific objectives, the next stage is to identify the outputs and inputs to the model, specifically the influential factors that will be included. A combination of literature review,

observations on two case studies, and interviews with domain experts were conducted to decide on the influential factors to be modeled. The factors justification from the literature is presented in Table 4-1. Interest/motivation to achieve higher value, knowledge or experience in the project type, influence over the team, clarity of value attributes, network closeness, stakeholder engagement, collaboration, and project complexity were all discussed in the literature as factors influencing project value fulfillment. Based on these factors, the conceptual model was then developed. The assumptions and simplifications usually made during the modelling process are discussed in the subsequent sections when explaining the model components. The conceptual model is represented in Figure 4-2.

Table 4-1 Factors justification from AEC literature

Factors included in the model	**Justification**	**Reference**
Interest/motivation to achieve higher value and project outcomes	"We used the model to explain how the project team's capability, **motivation**, and speed of making the best-for-project decisions ensure that the value creation goals are met." (p.1) "Project team features such as capability and **motivation**…have strong influence on delivering a valuable project outcome" (p. 5)	(Pargar & Kujala, 2021)
Knowledge or experience in the project type	"When it comes to achieved value, knowledgeable clients have more chance to reach a higher level of achievable project value" and "high ability AE teams are more likely to require less time to converge to a final design solution that satisfies the client's value" (p.18)	(Abou-Ibrahim & Hamzeh, 2022)
Influence over the team/ power play	"This paper offered an explanation of how stakeholders might **influence** the outcome of projects and illustrated how they can be identified and their **power** and influence measured." (p. 658). "The ability to understand the often-hidden **power** and **influence** of various stakeholders is a critical skill for successful project managers. Stakeholders can be a considerable asset, contributing knowledge, insights and support in shaping a project brief as well as supporting its execution" (p.650).	(Bourne & Walker, 2005) and (Yang et al., 2009)

Factors(continued)	Justification	Reference
Clarity of value attributes and value expectations	"Sense-making among multiple stakeholders can lead to the **clarification** and identification of value dimensions, which can be subsequently used to identify a set of key result areas that more clearly articulate value." (p. 22). Sense-making in this study was associated with consulting with stakeholders, engaging them in the process early on to **clarify** and align value expectations.	(Ang et al., 2015)
Network parameters (graph density, network closeness, etc.)	"Our results indicate that assigning a project developer/leader role to central actor and forming the **tightly knit core network** both played important roles in the front-end value creation. Highly **dense network** allowed fast information flow between parties and building trust between actors, which turned out to be valuable when the project idea was pushed forwards." (p. 1233, 1234). "The results indicate that **highly connected network** structures can facilitate the interaction between the stakeholders to achieve alignment." (p.1)	(Matinheikki et al., 2016) Stephan and Menassa 2014
Stakeholders' engagement in design	"An important component of value management is the ability to understand and manage multiple stakeholder requirements, transforming them into product and process specifications. One important step is identifying upfront who are the **key stakeholders** that need to be **involved** in the design process or might be affected by and influence the project's outcomes." (p.14).	(Tillmann, 2018)
Collaboration on project / project delivery approach	"… this study empirically demonstrates that jointly **coordination** and **collaboration** drive two logics of value creation in construction projects, impacting significantly on project value." and "when the project is governed under a relationship approach, value co-creation is the primary dominant logic where relational engagement (i.e., continuous interactions and relational norms) and collaboration influence project effectiveness." (p. 325).	(Heredia-Rojas & Liu, 2016)
Project complexity and uncertainty	"The results present how endogenous and exogenous drivers of system behavior unfold over time and provide a richer understanding of the effect of various model structures such as **project complexity** and **uncertainty** on value creation." (p.1)	(Pargar & Kujala, 2021)

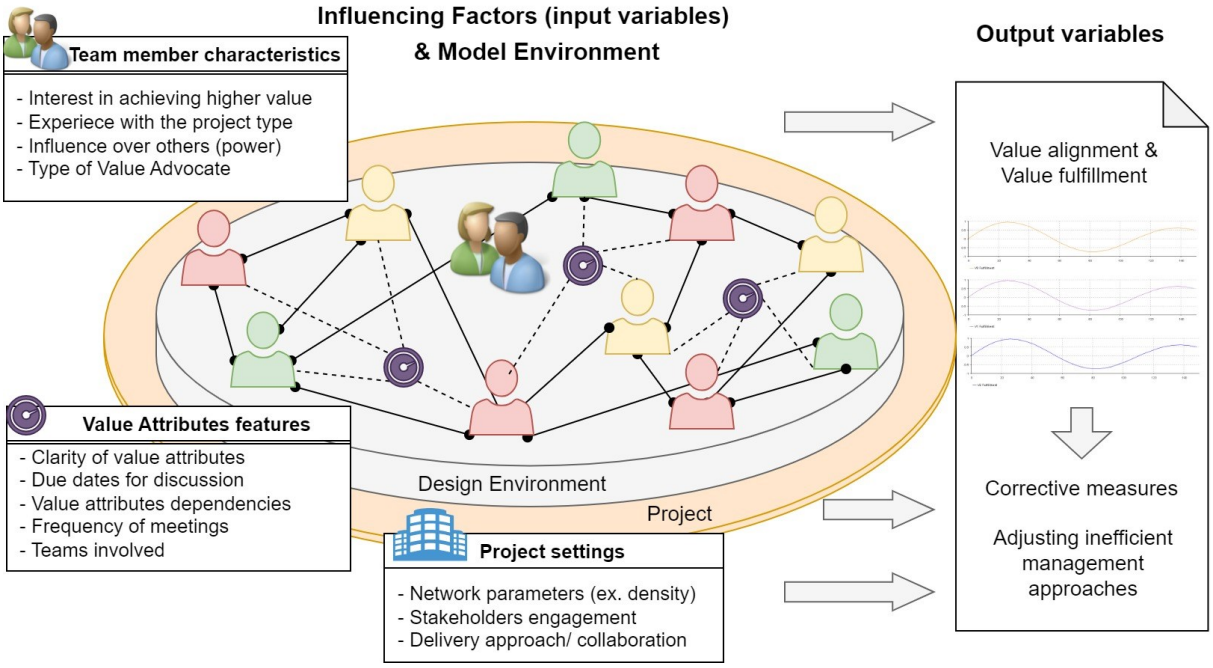


Figure 4-2 Conceptual model

The conceptual model reveals the scope of the model. Three major categories are modeled and have direct impacts on value alignment and fulfillment outcomes: team members' characteristics, value attribute characteristics, and project setting. The factors identified earlier from the literature (Table 4-1) and from our discussions with the construction managers as domain experts are included under the relevant category. One exception for this inclusion is project complexity and uncertainty, which were not modeled separately but rather factored into the clarity of value attributes for simplification. Additional factors were added under the value attributes characteristics to address planning aspects, including determining the timing for discussing these attributes, specifying the teams responsible for their implementation, and stipulating the frequency at which the team will revisit them during the design phase. In this research, the authors are addressing the value propositions that relate to the product and the outcome, not the processes. Product-related value propositions pertain to the attributes and qualities of the final deliverable or end product; these might include, for instance physical functional characteristics, structural

integrity, safety, mobility and accessibility, and energy efficiency. Process-related value propositions are attributes that relate to the practices and procedures during project execution. They refer to project management techniques, communication protocols, and team culture. The latter category should undergo monthly assessments and simple evaluation techniques. The former category, however, necessitates progressive planning with design iterations, making it more uncertain and requiring the engagement of various parties, such as various disciplines, end-users, government agencies, regulatory bodies, suppliers, and others. Hence, the suggested model helps managers make informed decisions towards the product-related value propositions. The factors under each category are defined under the model components section.

In connection with the conceptual model, Figure 4-3 depicts a conceptualizing of value evolution on projects. The model abstracts the translated value propositions from each team as separate nodes (bubbles). These nodes are introduced in the phase where input is received from the corresponding party. In integrated project settings where a diverse core team is engaged early on, most nodes are seen in the preliminary design phases. Throughout the project phases, nodes evolve through communication and interactions among the parties. Notably, project value appears as a distinct node in Figure 4-3 (turquoise color) to highlight that it results from these interactions and value communications among parties. It is essential to emphasize that project value is not merely the sum of value perceptions by the parties; rather, it represents the output of communication at a specific point during the design process. As a result, the project value node differs from the owner's-value node (represented in orange). At the top of Figure 4-3, four ultimate value considerations, usually highlighted in the literature, exert influence on designers involved in the design process (i.e. social, economic, environmental, and political value considerations on projects).

The conceptual model and the abstraction in Figure 4-3 influenced the model's development and logic. For model simplification, the evolution of value propositions was considered in equal increments whenever the team meets and successfully improves value. The following section provides further explanation regarding value improvement and alignment during design progress.

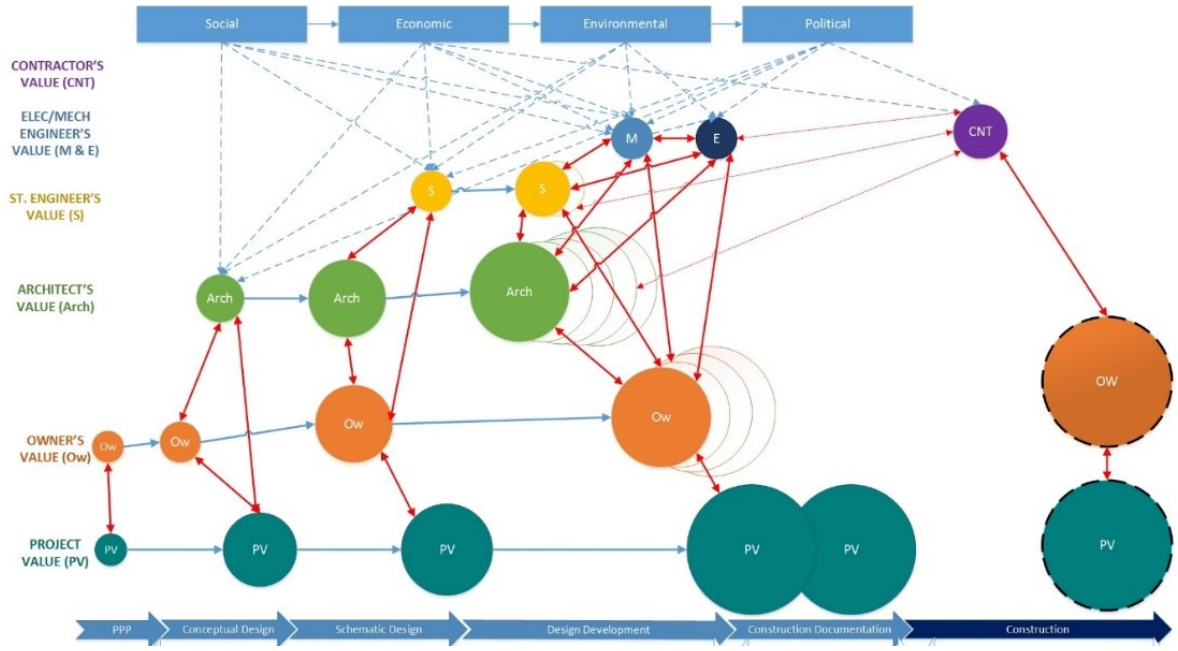


Figure 4-3 Conceptualization of the evolution of teams' value propositions along the project phases and the resulting evolution in project value based on teams' interaction

4.3.3 Model Components

Agent-based simulation models represent individual agents that interact together in a certain environment. These agents have attributes or state variables and behavior rules. These models also include the methods of interactions among the agents and the environment in which agents interact (Macal & North, 2007).

4.3.3.1 Value attributes/propositions as agents and their attributes

The first agent type is a value attribute (VA) identified on a project. Each value attribute has a set of parameters that need to be provided by the project manager or the team. Five parameters were identified and shown in Table 4-2. These parameters are:

- *ID for each of the value proposition* (and their respective description): the value description should be as thorough as possible; the clarity of the identified propositions is evaluated separately.
- *1st due date for discussion*: project managers identify the date on which the team would meet and discuss how to translate this value proposition into design. Note that the first encounter could be within a specific team responsible for brainstorming about this value proposition, or this first meeting could be across different teams. Usually, in a collaborative delivery, like Integrated Project Delivery (IPD), value attributes are brainstormed together with multi-disciplinary teams. After the first meeting, the frequency of discussions needs to be identified.
- *Dependencies between Value attributes*: interdependencies between value attributes are a fact, therefore, teams need to incorporate these interdependencies when planning their execution. Sometimes, the team cannot start discussing a particular attribute until its predecessor has been addressed – or partially addressed for that matter.
- *The responsible teams and the frequency of their meetings*: during the value planning phase, for each value attribute, or set of value attributes, there should be identification of the responsible team and the frequency at which they need to assess the progress on these attributes. The responsible team(s) characteristics are core to achieving alignment and

fulfillment, as we will see in subsequent sections. These two parameters are important for the model, as decisions related to them can significantly influence the results.

Table 4-2 Parameters and Variables for the value attribute agent

	Agent Population: Value Attributes	Ranges/categories
Parameters	1. ID	Integer
	2. First discussion due (weeks)	Integer
	3. Prerequisite value(s)	ID
	4. Frequency of discussions (per month)	Integer
	5. Involved team(s)	Team Name
Variables	1. Clarity	Qualitative (1-3)
	2. Value improvement	Integer out of 100
	3. Value fulfillment	Integer out of 100

In addition to the parameters, three variables are associated with the VAs, these are:

- *Clarity of the VA*: at the phase where the model is employed, the project manager collects feedback on the clarity of the identified value attributes. For simplification, we used a 3-point scale, where each VA is evaluated if it is not clear (level 1), somehow clear but still needs clarification (level 2), or clear/very clear (level 3). Clarity is considered a variable since the more teams meet and discuss, the higher chances the clarity would increase (Ang et al., 2015). In the model, clarity is automatically set to increase from one level to another after a certain number of meetings are conducted.
- *Value improvement*: this score represents the incremental improvements of a certain value attribute arising from intra-team discussions. It is contingent upon both the attribute clarity and the characteristics of the individuals responsible for executing it within the team. Thus, it is related to Equation 1 described in the mathematical model section.

- *Value fulfillment*: is an output variable of this model. It is calculated based on Equation 2 (after improvement) and Equation 4 after high fulfillment. The equations are discussed in the mathematical section.

4.3.3.2 Team members as agents and their attributes

Each team member must be modelled as an agent in the agent group team_members. All stakeholders participating in design will also be modelled, and their communication frequency with other team members should be documented. Additionally, for each modelled member, the following characteristics need to be identified:

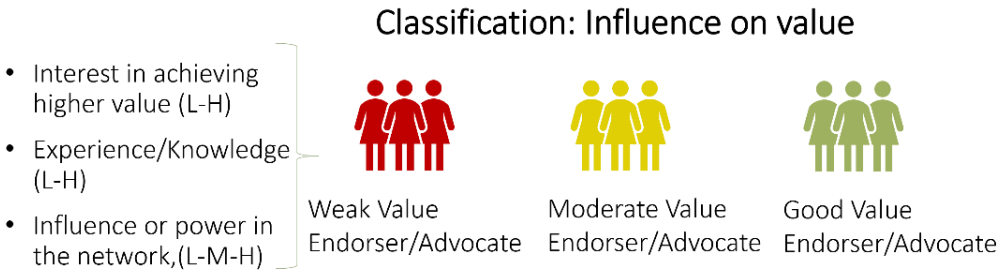
- *Role within the team*: this parameter indicates whether the participant is a lead in their team (i.e., lead designer or project manager) or a regular member in the team.
- *Influence or Power play*: Does the team member have a low or high impact on the design and the decision-making process? Usually, the project manager inputs this information based on the formal authority given to these individuals on the project. In other words, if the agent has a lead role, their influence or power play is automatically high with a specific assigned value for high power. If the member is not the lead, their influence might be medium or low.
- *Interest/commitment*: Is this team member engaged when value discussions are present? Direct observations can provide insights into teams' interests and commitment. Specific indirect questions could also be distributed in the form of a questionnaire. According to Freeman et al. (Freeman et al., 2007), recognizing stakeholder interests is a crucial undertaking for managing stakeholders where leaders need to think about the "Value Creation Question: how can we create as much value as possible for all of our stakeholders?" (Freeman et al., 2007). Pirozzi (Pirozzi, 2017) explained about categorizing

stakeholders based on their prevalent interests with the help of behavioral models. Mendelow's model investigates the power/interest matrix by analyzing: how interested is each group in expressing its expectations and forcing it into the project decisions; Do they have the power to do so? (Mendelow, 1981; Olander & Landin, 2005). Interest is usually driven by understanding the purpose of doing a specific task. This sense of purpose can be instilled within team members by other influential parties or leaders and can improve project outcomes (DuBois et al., 2015). These dynamics also need to be incorporated into the model. Tools for studying stakeholders and their influence have been provided in the literature, the authors suggest looking into the Stakeholder Interest Intensity Matrix explained in Bourne and Walker 2005 (Bourne & Walker, 2005).

- *Experience or knowledge*: this refers to each team member's knowledge, skills, and abilities to contribute to value propositions and be creative in resolving conflicts.

These three influencing factors were used to classify participants or show their advocacy type. Particularly, team members and involved stakeholders are classified as value advocates based on their scores in the criteria mentioned above (refer to Figure 4-4). The homogeneity of agents is assumed where people in the same category of value endorsers are expected to have the same behavior outcome, hence the same decision-making output. Agents in this model have adaptive behavior where the model allows agents to adapt and learn based on their interactions with other team members. To elaborate, two of the influencing factors – interest and knowledge, are considered variables, while influence/power is considered a parameter in this model (Table 4-3). This means that as interactions between participants occur, interest and knowledge change, leading to shifts in the resulting advocacy category. This change is contingent on the interplay of the two factors.

Following up on the advocacy type, the different combinations of the three factors lead to classifying participants as weak value advocates, moderate advocates, or good advocates, as shown in Figure 4-4. For instance, team members who have (a) low interest, (b) minimal experience in working on the identified value attributes, and (c) have little to medium influence are considered weak value attributes. When a particular team has most of the team members as weak advocates, it is more likely that value attributes will take some time to get improved. Additionally, the same team will have a low chance of achieving alignment easily on projects. This assumption was discussed and validated with practitioners and experts with long experience in the industry. We requested that they identify the relative importance of each advocate on improving value. The obtained weights were incorporated into the model to reflect the differences in advocates (weak, moderate, and good). Note that the used weights are not universal across projects. Managers may evaluate those weights differently and such variations are acceptable. This acknowledgment stems from the fact that each project and team possess distinctive characteristics. The designated weights serve the sole purpose of reflecting in the model that having more good advocates on the team accelerates the value fulfillment process.



	Weak	Moderate	Good
Interest – Knowledge- Power	LLL	LHH or LHM	HHH or HHM
	LLH or LLM	HLL	HHL
	LHL		HLH or HLM

Figure 4-4 Classifications of Value advocates

Table 4-3 Parameters and variables for the team member agent

	Agent Population: Team member	Ranges/categories
Parameters	1. ID	Integer
	2. Role	Lead or member
	3. Team	Arch, mech, contractor, etc.
	4. Influence/power	Low – Medium - High
Variables	1. Interest	Low - High
	2. Knowledge	Low - High
	3. Advocacy	Weak- Moderate- Good
	4. Team's improvement probability	Equation 1
	5. Team's fulfillment	Equation 2
	6. Alignment Indicators score	Equation 3

In addition to the above, three more variables are linked to team members but are reflected in their behavior; these are: team's improvement probability, Team's value fulfillment, and Team's alignment probability. However, since all three variables depend on interactions among the different teams and on other factors in the project, they are explained in the mathematical model section with their relative equations (equations 1, 2, and 3).

4.3.3.3 Interactions and relationships

The model steps and agents' interactions are represented in the flow chart – Figure 4-5. The initial state for team members is designing (or if other stakeholders are included, the initial state would be *working*). The simulation commences when a meeting is initiated through either the pre-set meeting date or if the dependencies have been fulfilled and the team needs to discuss. The model accounts for two meeting types: intra-team communications (within the same team) and inter-team communication (between teams). When members go for the intra-meeting, value improvement is checked for. There is a chance that after the meeting, the value is improved or not. The probability of a value attribute getting improved by the intra-team discussions is based on calculating the probability according to equation 1, discussed later. If the value is improved, value fulfillment

increases with one increment. If the value is not improved, there is no increase in fulfillment. Once the multiple value improvements yield level 1 of a% fulfillment, where a% is the first checkpoint when alignment is due (check the value meter illustrated in Figure 4-6 – in this research the 1st checkpoint was considered at 30%), then alignment across teams must be checked for. The team leaders will then proceed to inter-team discussion to check alignment. After conducting the inter-team meeting, teams are either aligned where they agreed on most of the ideas regarding the value attribute or not aligned, indicating low alignment. The alignment score ($S_{(alignment)}$) is calculated using equation 3 and discussed in later sections. In the case of high alignment, the value fulfillment remains the same (meaning if it was a% improved, it would stay at a% at level 1). However, in case of low alignment, value fulfillment decreases in a specific %Y which will be discussed in equation 4. This process continues until all value attributes' fulfillment level reaches 100%.

Emergent behavior of agents is part of any agent-based modeling. To define agent behavioral rules, there are several methods expressed in the literature. In this research, and accounting for the subjective uncertainty, two approaches were utilized: the expert-driven approach and using theories from past literature. These approaches were employed to establish behavioral rules for the agents or team members. This expert-driven approach relies on the judgement and expertise of domain experts to define these rules (Raoufi & Robinson Fayek, 2018). Past literature is helpful in situations where data is scarce, yet there exists reliable literature that outlines such behavioral rules. Therefore, predefined roles are inserted into the model that were based on experts and literature, including the changes in interests, knowledge, and clarity upon agents' interactions:

- *Change in interest based on interactions*: "The more influential and assertive stakeholders can sway others in the project team to align their values and reach common ground and

consensus among stakeholders" (Martinez-Moyano et al., 2011). Leaders can motivate and inspire their team and stakeholders to embrace change and pursue strategies and tasks essential for achieving the set of goals (Prabhakar, 2005).

- *Change in knowledge based on interactions*: "stakeholders […] deepen their knowledge in this area by interacting on an ongoing basis" (Wenger et al., 2002).
- *Change in the clarity based on interactions*: "We also show how unarticulated or unknown value expectations need to be clarified in consultation with other partners and internal stakeholders to start to identify, clarify and align individual with external and internal stakeholder value expectations. This finding suggests that sensemaking practices can help facilitate the identification, clarification and alignment of multi-stakeholder value-dimensions and expectations for project and portfolio decisions and outcomes." (Ang et al., 2015).

Consequently, the modelers incorporated a general rule that applies to meetings within the same team or across different teams. According to this rule, when members with lower interest and knowledge levels interact with those who have higher interest and knowledge, their own knowledge and interest levels will increase slightly by increments to reach a certain threshold. The knowledge and interest levels vary from 0.1 to 0.9 on the basis of no knowledge/interest is null or zero nor knowledge/interest is perfect or 1. As for value clarity, upon interaction within or between teams, the knowledge shared between members will assumingly clarify information (Ang et al., 2015), thus increasing also the clarity of a value attribute by a slight incremental increase.

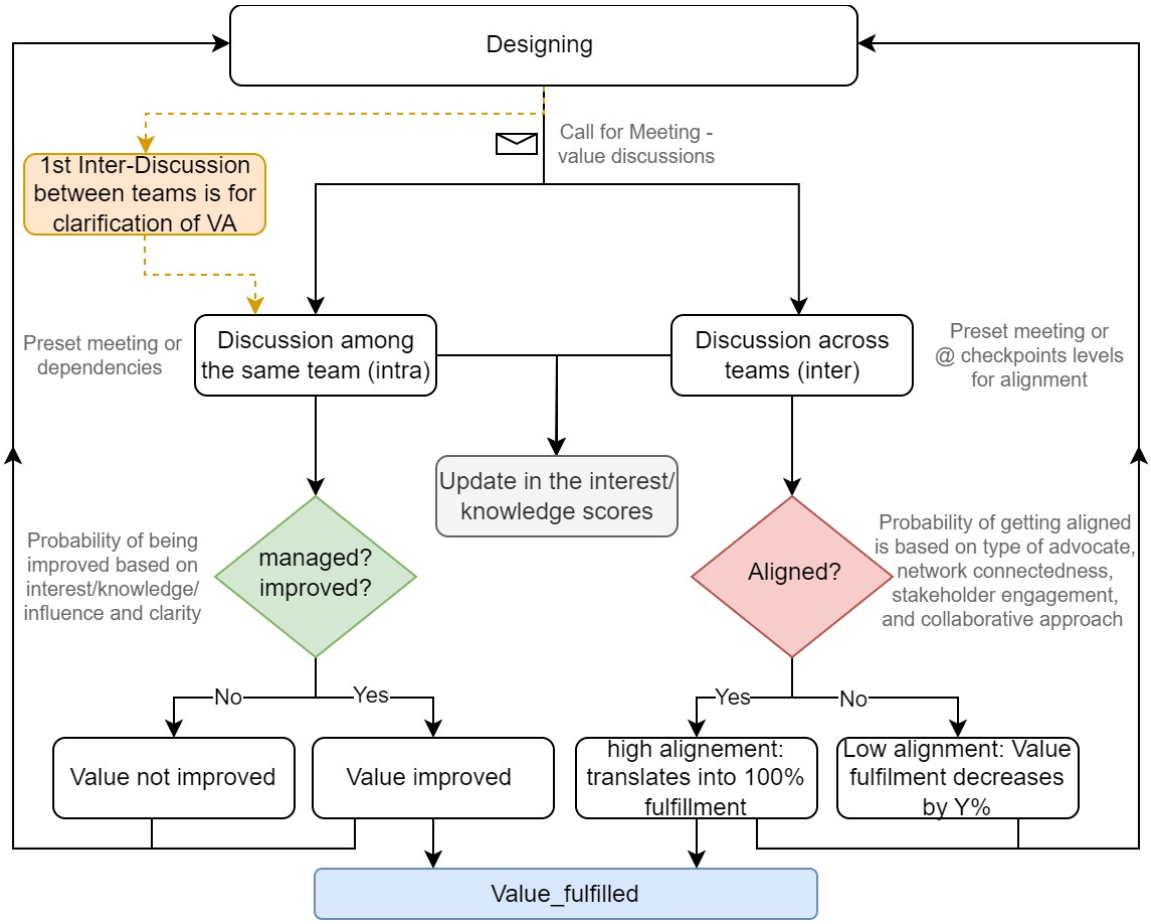


Figure 4-5 Activity diagram for the team members

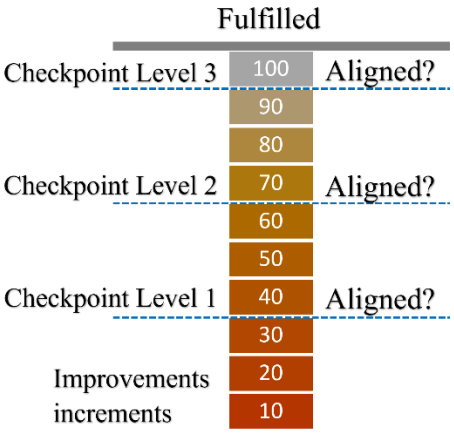


Figure 4-6 Value Meter recording value fulfillment based on improvement increments. Alignment checkpoints levels need to be agreed on.

4.3.3.4 Model environment

The environment considered in this research is the design phase of construction projects, where project teams interact. Specifically, the communication network formed by these interactions describes the topology of the simulation model. Social Network Analysis is utilized to assess communication on projects and serves as a foundation for uncovering the connections within the model. Khalife et al. (2023) introduced a framework for gathering data to build a value communication network. This approach is relevant in the current context to identify the model environment topology.

The authors must emphasize that different delivery approaches impact the rules of interactions among members within their environment, especially concerning the parties involved in value discussions. In integrated project delivery projects (IPD), critical decisions in inter-discussions are made by the project management team (PMT) and project implementation team (PIT) captains. In contrast, in traditional settings, inter-team discussions may primarily involve the owners' representative and the consultant team during the design phases, as they are the only entities entitled to be on board based on the delivery approach and contract type.

4.3.4 Mathematical model

In the mathematical model, important equations were formulated to calculate variables, including value improvement, value fulfillment, improvement probability, and alignment probability. The first step involves identifying the influential factors that impact each of these variables. In the second step, project managers must determine the weights of each factor by assessing their relative importance. To achieve this, multiple methods found in the literature can be used, including factor analysis, factor loading, and analytical hierarchy process (AHP) (as referenced in (Raoufi & Fayek, 2018), (Yang et al., 2009), and (Darko et al., 2019)), providing managers with the flexibility

to choose the approach that best suits their implementation needs. The general equations used in the model are presented hereafter.

4.3.4.1 Probability of value being improved or Team's improvement probability: (Equation 1)

The factors affecting probability of a value attribute being improved are interest, knowledge, influence/powerplay, and clarity of the attribute. The probability of improvement of value attribute *i* by individual *j* is calculated through equation (1):

$$P(\text{improvement})ij = W1 * F(\text{Interest})j + W2 * F(\text{Knowledge})j + W3 * F(\text{Influence})j + W4 * F(\text{Clarity})i$$

W_n is the weight of each of the factors affecting probability of improvement. The sum of weights should be equal to one ($\sum W_{n\,(0\,-\,4)} = 1$). The weights in the model equation are project dependent. For example, in a collaborative delivery approach, less weight is assigned to influence or power since such approaches offer equal opportunities for team members to express their ideas and have a say in the decision-making process.

4.3.4.2 Equation for Team's fulfillment (Equation 2)

When value is improved as a result of high improvement probability, the team's fulfillment score increases by one increment. For each team, the model records the fulfillment score. The average of these teams' fulfillment is thus calculated and recorded by the model as per equation 2 below; once this average reaches the checkpoint level agreed on (in this case, the project manager advised at 30% (level 1), 60% (level 2), and 90% (level 3) improvement on the value meter), then the check for alignment among all teams is initiated. This assumes that all teams are equal contributors to this value attribute and equally responsible for its implementation. If not, simple incorporation of percentage responsibility distributed among the teams would be feasible. Accordingly, the equation associated with teams' fulfillment, which shows the value fulfillment score after improvements by multiple teams:

$$\text{Value fulfillment}_{(\text{after improvement})} = \sum(\text{Team1 fulfillment} + \text{Team2 fulfillment} + \text{Team3 fulfillment})/3$$

4.3.4.3 Alignment Indicators Score (Equation 3)

Griffith & Gibson (2001) explored factors that influence stakeholders' alignment in pre-project planning, identifying 10 key alignment issues. In this study, we have examined and drawn connections between these factors and those we have considered. The outcomes of this comparative analysis are presented in Table 4-4. The factors not addressed by the influencing factors incorporated in our model are regarded as best practices (practices (a) to (d) in Table 4-4). Managers should consider these while using the simulation model to conduct scenario analysis and testing. A recent study by Najafizadeh & Hamzeh (2023) specified more factors related to team members' characteristics that help in measuring team alignment based on the Target Value Design (TVD) approach. These factors can be considered when managers need to improve their teams' commitment and interest to enhance value fulfillment (for instance, team members have good problem-solving skills, members listen effectively and share constructive feedback, and members respect teams' diversity, etc.).

Table 4-4 Team alignment factors from Griffith and Gibson (2001) and their connection with factors present in this study

Alignment Factors from Griffith and Gibson	Relation to factors in this study
1. Stakeholders are appropriately represented on the project team.	Through Engagement factor
2. Project leadership is defined, effective, and accountable	Through Type of advocate
3. The priority between cost, schedule, and required project features is clear	*(a) Prioritizing in case of Trade-off (practice 1)*
4. Communication with the team and with stakeholders is open and effective	Through network connectedness factor
5. Team meetings are timely and productive	Through the planning conducted
6. The team culture fosters trust, honesty, and shared values	Through collaboration factor

Alignment Factors from Griffith and Gibson (continued)	Relation to factors in this study
7. The pre-project planning process includes sufficient funding, schedule, and scope to meet objectives	*(b) Realistic and balanced objectives (practice 2)*
8. The reward and recognition system promotes meeting project objectives	*(c) Incentives (practice 3)*
9. Teamwork and team building programs are effective	*(d) Health-check for teams (practice 4)*
10. Planning tools are effectively used	Through the planning conducted and through the proposed simulation tool which is part of the planning exercise

The alignment depends on the following factors: type of advocate, network parameters, end-user engagement, and collaboration level. The alignment indicators score that indicate whether a value attribute *i* is aligned and considered fulfilled by an individual j is calculated in equation (3):

$$S(\text{alignment})ij = C1 * F(\text{typeofadvocate})j + C2 * F(\text{network}) + C3 * F(\text{engagement}) + C4 * F(\text{Collaboration})$$

C_n is the weight of each of the factors or indicators affecting alignment. The weights are again project dependent. The sum of weights should be equal to one ($\sum C_{n\,(0-4)} = 1$).

The check for alignment occurs once a specific value attribute has been improved to a certain level by different teams (as explained earlier and in reference to the value meter – Figure 4-6). At this stage, the attribute requires coordination with other teams to ensure alignment, signifying agreement, and unified efforts towards the same goal. The flow chart depicted in Figure 4-7 explains the model's logic regarding alignment levels and the resulting value fulfillment scores that are described further in subsection 4.3.4.4 – Equation 4. The alignment benchmark revealed in the flowchart refers to the cut-off point for which the team is considered aligned. In other words,

beyond this point, the team is expected to be highly aligned, which reflects on the value being fulfilled up to the level of its improvement.

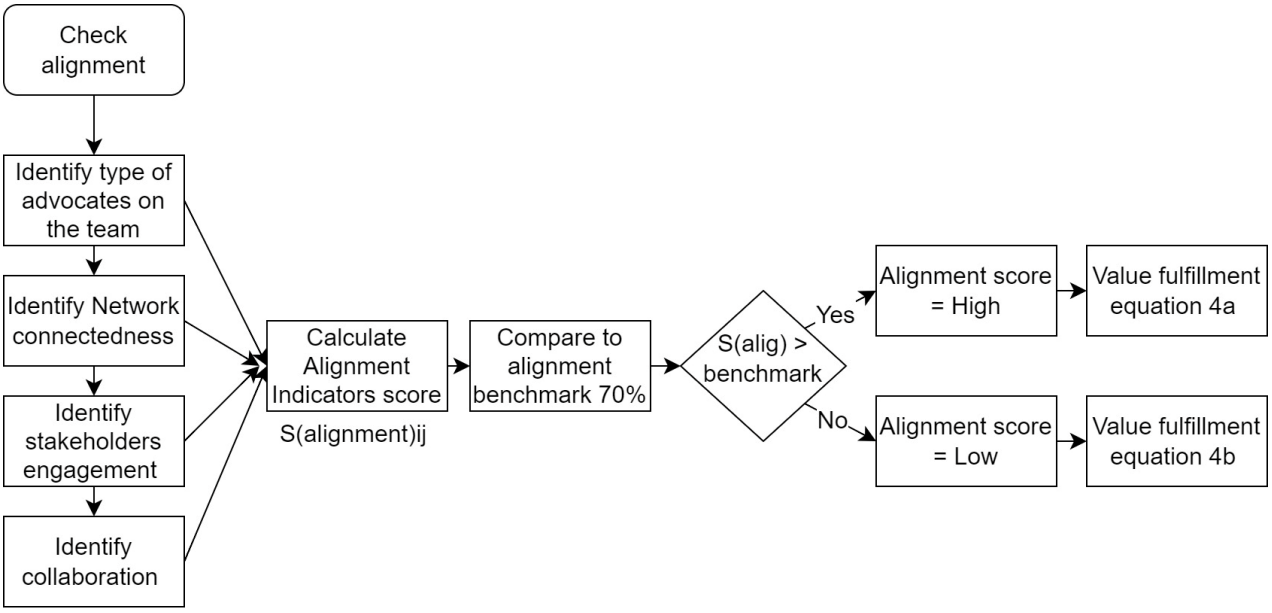


Figure 4-7 Flowchart of team alignment

4.3.4.4 Equation for value fulfillment based on alignment score (Equation 4)

- If the alignment score is high (> benchmark): reserve the value fulfillment score:

  Equation 4(a): Value fulfillment $_{(\text{after alignment})}$ = Value fulfillment $_{(\text{after improvement})}$

- If low alignment (< benchmark ~ for example, if it is set at 70% or 0.7): calculate fulfillment after alignment based on the checkpoint level (Table 4-5).

Table 4-5 Value fulfillment score after having low alignment.

Check points	Equation 4 (b) according to each checkpoint
At level 1	Value fulfillment $_{(\text{after alignm.})}$ = (Value fulfillment $_{(\text{after improv.})}$) * (0.3 + S(alignment)$_{ij}$)
At level 2	Value fulfillment $_{(\text{after alignm.})}$ = (Value fulfillment $_{(\text{after improv.})}$ – %level1) * (0.3 + S(alignment)$_{ij}$)+ %level 1*
At level 3	Value fulfillment $_{(\text{after alignm.})}$ = (Value fulfillment $_{(\text{after improv.})}$ – %level 2) * (0.3 + S(alignment)$_{ij}$)+ %level 2*

*The equations are formulated in this way to reserve fulfillment at previous value alignment checkpoint.

4.3.5 Computational model

Based on the previous factors, equations, and flow chart, the computational model was incorporated into AnyLogic. The agents' representation and the behavioral states in the model are depicted in Figures 4-8 and 4-9 for the team member agents and the value agents, respectively.

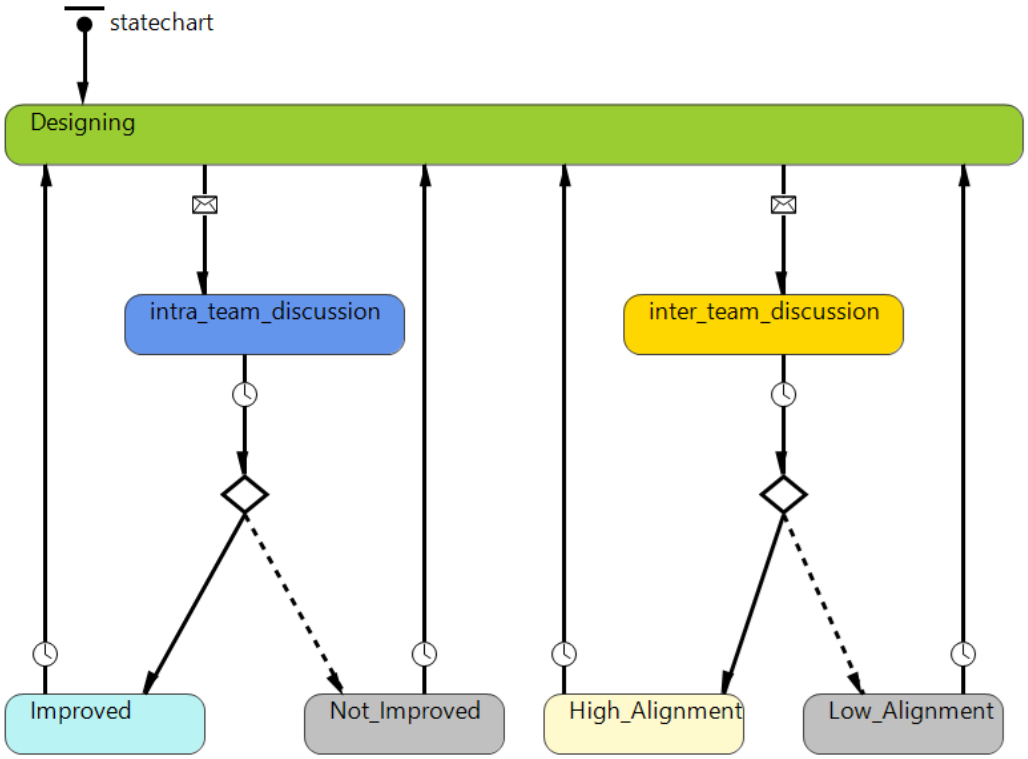


Figure 4-8. State chart of the agent type Team member in the AnyLogic simulation model

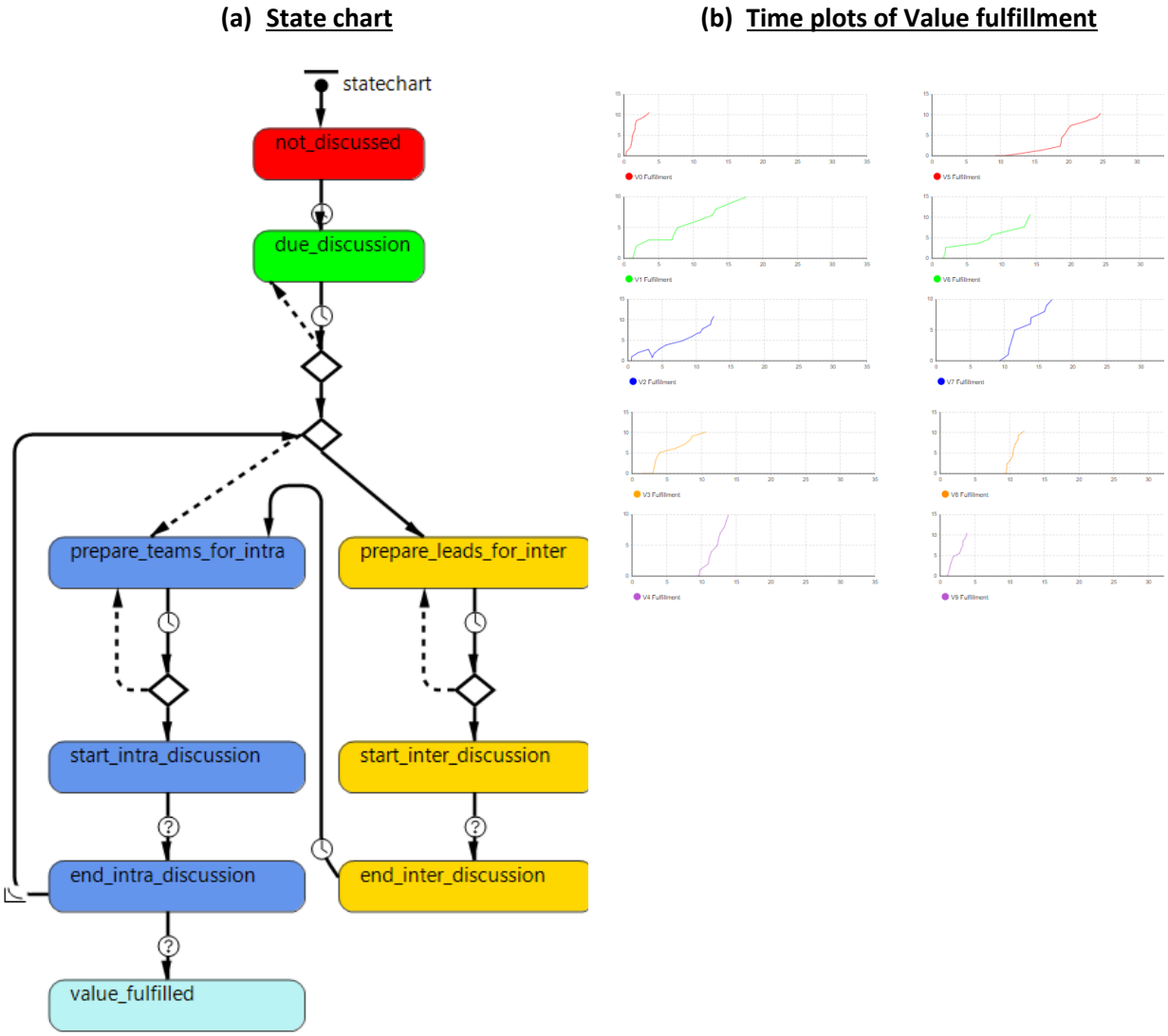


Figure 4-9. (a) State chart of the agent type Value and (b) time plots for value fulfillment levels resulting from the AnyLogic simulation model.

Figure 4-8 outlines the two primary states for team members, including intra-team discussions and inter-team discussions resulting in value improvement and value alignment and fulfillment, respectively. Figure 4-9 (a) illustrates the different states through which the value agent transitions, which also relate to the discussions within and among teams. The time plots are previewed (Figure 4-9 (b)), representing the value fulfillment output variable.

The computational model was tested, and simulation experiments were performed using random values to assess the dynamics among the different factors and observe the variations in model variables. The behavior of the system was observed. The different runs served in determining errors in the model and to improve the overall performance. The results confirmed its usability in providing a timeline to achieve value fulfillment. Additionally, two extreme values for team characteristics were introduced to verify the model's functionality. These two scenarios served as a verification of the computational model's reliability and accuracy (further information is explained in the section Model Validation and Verification). To further test its accuracy with respect to real projects, a case study was applied, the details of which will be discussed hereafter.

4.3.6 Model application on actual project

The case study provided validation for the model used in this research. The selected project is an academic building for a public university, involving a renovation of the existing structure and the addition of a new building. Sustainability was a key aspect of the building's design. The contract type was CM at risk. During the design process, active participation from diverse user groups, including students, staff, and faculty, was sought. The value propositions or attributes resulting from these collaborative efforts are presented in Table 4-6. The first author was involved for a course of 14 months in this project, attending design coordination meetings, sending out surveys to collect responses on value fulfillment, studying communication using the SNA method, and meeting regularly with design managers to discuss progress. Since the results from the actual project are available, the model was tested against these results to check its validity. The model was populated with the actual numbers, and any missing information was obtained from the project manager.

Table 4-6 Description of the Value propositions for the case study

ID	Value Proposition Description
V0	Supporting academic programming requirements
V1	Enhancing well-being through food services
V2	Empowering learning and knowledge exchange through adequate bookable meeting spaces
V3	Promoting cultural diversity and equity through indigenous recognition
V4	Boosting users' comfort through relaxing lounge spaces and ergonomic design
V5	Having the Right to Light: Acoustics and maximizing daylight views
V6	Enabling scalability, adaptability, and future expansion with flexible design
V7	Selecting durable materials with low operational and maintenance requirements
V8	Simplifying operations, enhancing efficiency, and achieving optimal performance with thoughtfully selected and user-friendly technologies
V9	Delivering cost-effective solutions, greater affordability, and competitive pricing for enhanced value

The major milestones during design were identified, and the assessment of network connectedness and user/stakeholder engagement in the different phases were evaluated and reported in Table 4-7. The model was then tested based on these inputs, and the results are discussed in the following section.

Table 4-7 Design phases and details of network connectedness and engagement

Design actual duration 27 months	Phases range	Time (months)	Network Connectedness	End-user/ stakeholder Engagement
May-Dec 2021	P1 – 8 months	$T \leq 8$	Low	Yes
Jan-April 2022	P2 – 4 months	$8 < T \leq 12$	Medium	No
May-Aug 2022	P3 – 4 months	$12 < T \leq 16$	Low	Yes
Sep – Dec 2022	P4 – 4 months	$16 < T \leq 20$	High	Yes
Jan- July 2023	P5 – ~7 months	$T > 20$	High	No

In this research, the AHP was used to determine the weights of the factors in the context of the case study. The steps followed in AHP were the following: (1) establishing a hierarchy of the criteria or factors, (2) performing the pairwise comparisons between each element of the hierarchy, and assigning a relative importance number according to the scales by Saaty (Wind & Saaty, 1980) which include a scale from 1 to 9 where 1 represents equally important factor, and 9 absolute more important factor and the ranges in between, and (3) deriving priority weights by applying mathematical calculations. The authors also performed a consistency check to ensure the reliability of the pairwise comparison and avoid inconsistencies. The consistency ratio was checked to be less than 2% for the responses gathered from the project management team. Usually, matrices developed for factor comparison are actually consistent when their consistency ratio is less than 0.2 (Wedley, 1993). Applying the AHP to obtain the relative importance of each advocate on improving value, the weights for the weak, moderate, and good value advocates were determined to be 0.07, 0.25, and 0.68, respectively.

4.4 RESULTS & DISCUSSIONS

4.4.1 Results discussion

One of the output variables of the developed simulation model is value fulfillment for each identified value attribute. Following the model's development, the authors conducted the simulation experiment on the ten value attributes and eight involved teams with a total of 40 members connected through communication. The results obtained from the applied case study are recorded in Figures 4-10 and 4-11. Figure 4-10 presents graphs showing the evolution of value fulfillment over time (in months). The reported value fulfillment levels range from 0 to 10, with 10 indicating 100% fulfillment. Figure 4-11 records the start and end points of each value attribute fulfillment. From analyzing both graphs, the authors made the following observations:

First, the time plots depict a general increasing trend in value fulfillment; however, each plot exhibits varying slopes, indicating differences in the rate at which value fulfillment progresses over time. Due to the influence of different factors on value improvement and alignment, and due to the emergent behavior and the learning that happens along the way, it is difficult to predict which value attribute will achieve fulfillment faster and how each value attribute will progress without the help of simulation.

Second, a drop in value fulfillment was observed in value attribute 2, where a decrease in value was recorded when the teams were called for a value alignment check. The results indicate that low alignment was reached, which caused a decline in value fulfillment. The teams, at this point, need to conduct further internal meetings (intra-team discussions) before reconvening to verify alignment with different teams and incorporate this attribute into design effectively and mutually. This drop helps teams develop a deeper understanding of each other's perspectives and encourages them to consider alternative solutions. This behavior aligns with Tuckman's team development model (Tuckman & Jensen, 1977), which goes through forming, storming, and norming stages. The decrease in value fulfillment is an aspect of the storming phase, where different perspectives exist before reaching a common understanding.

Third, the time plots revealed the dependencies between attributes, where value attributes 4, 5, 7, and 8 only commenced once their predecessor relationships were achieved, which occurred at 9.2 months into the design process. Monitoring dependencies is crucial, as they significantly impact the overall duration for resolving and fulfilling value attributes. Notably, the dependencies in this case study were set at 50%, meaning the successor value attribute cannot start until at least 50% of the predecessor work was fulfilled.

Fourth, the results revealed significant variations in the time needed to achieve fulfillment for different value attributes, with the minimum being 2.8 months (value attribute 8) and the maximum being 15.4 months (value attribute 5). At first glance, one might assume that the disparity comes from differences in clarity and from the frequency of discussion assigned for each attribute. Yet, upon further analysis of the factors, the findings unveiled a deeper insight. For the fastest attainment, it was observed that the value attribute had a dependency, thus, did not initiate until later in the project. However, by that point, the team had accumulated sufficient knowledge and interest (as evident from the emergent behavior) to execute this attribute rapidly. Additionally, for the slowest fulfillment, although it commenced later due to the dependency rule, one of the teams responsible for this attribute had fewer responsibilities, resulting in less interaction with the team. Furthermore, the attribute's lower frequency of discussion compared to other attributes played a role in slowing down its fulfillment process. These observations emphasize the complexity and multifaceted nature of the factors influencing value attainment, and the interplay between clarity, frequency, dependencies, and team characteristics all play a vital role in determining the time needed to achieve value fulfillment for different attributes.

Fifth, based on the recorded data, the average time required to fulfill this project's attributes was 8.7 months. When analyzed alongside other project factors, this information offers insight into the speed at which target objectives can be accomplished through the design phase. It also allows for assessing whether the chosen design approach aligns with the desired completion date. If not, then adjustments could be made and incorporated into the model to see their impact. In some cases, adopting a slower pace in the initial stages might prove beneficial in exploring various options, such as applying the lean principle of set-based design. This approach focuses on maintaining

flexibility in options, allowing for more exploration of possibilities before committing to one design.

Moreover, value attribute 1 had a stagnant behavior for the period spanning from 3.5 to 7 months. This result can aid managers in addressing this issue when they observe a lack of progress within the team. Managers can facilitate discussions and take corrective actions to reinvigorate progress by bringing the team together during this period. As for the graph of Value attribute 3, it reveals a delay in its initiation, which can be attributed to either uncertainties in the project leading to this delay in the start or to design clashes that hindered the improvement in this value attribute.

Finally, certain value attributes, such as V4 and V8, showed a rapid fulfillment rate, achieving high levels of fulfillment within a short period. This could be interpreted positively as a sign of effective team collaboration and clear implementation strategies. However, it could also raise concerns, as it might pressure the team to rush implementation. An aggressive increase in fulfillment is not always advisable, as value requires time to mature.

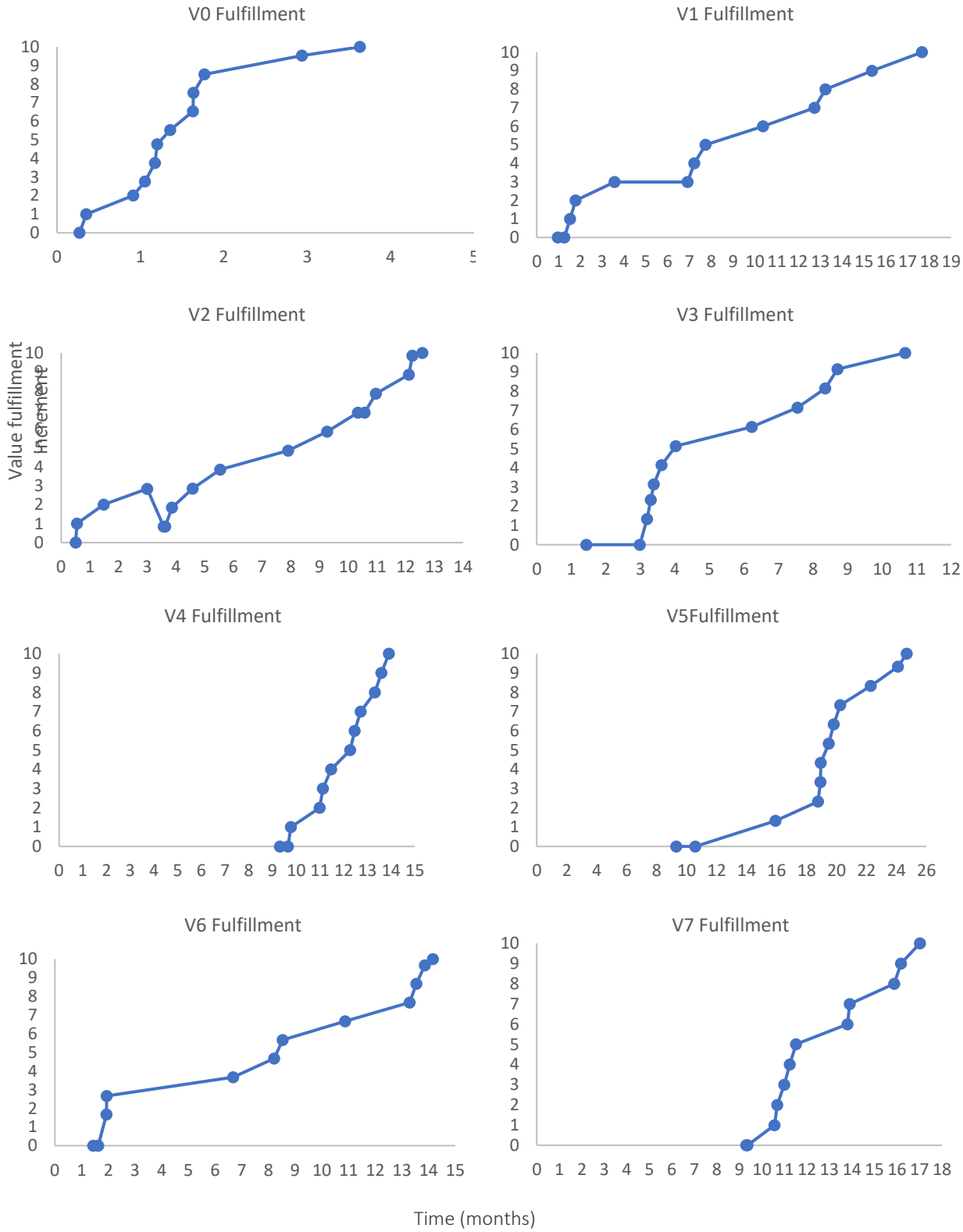


Figure 4-10 Time plots for fulfillment of the 10 value attributes

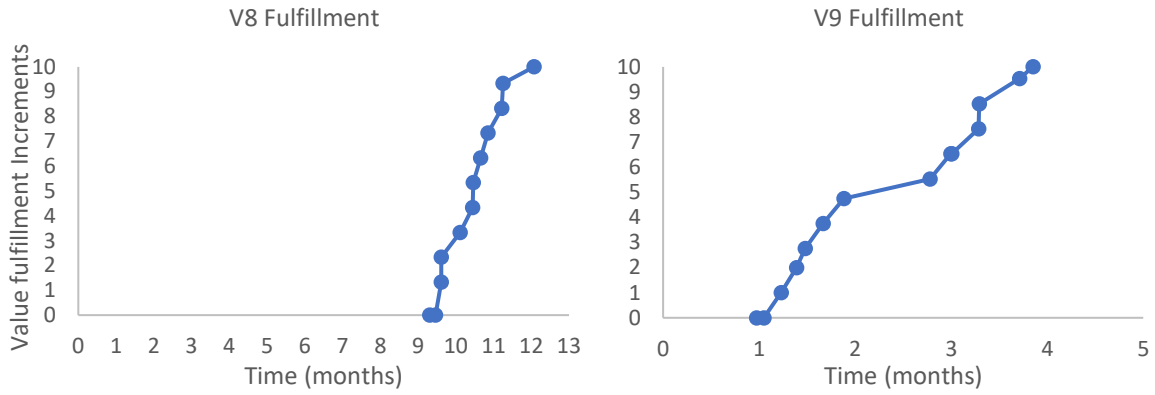


Figure 4-10 Time plots for fulfillment of the 10 value attributes (continued)

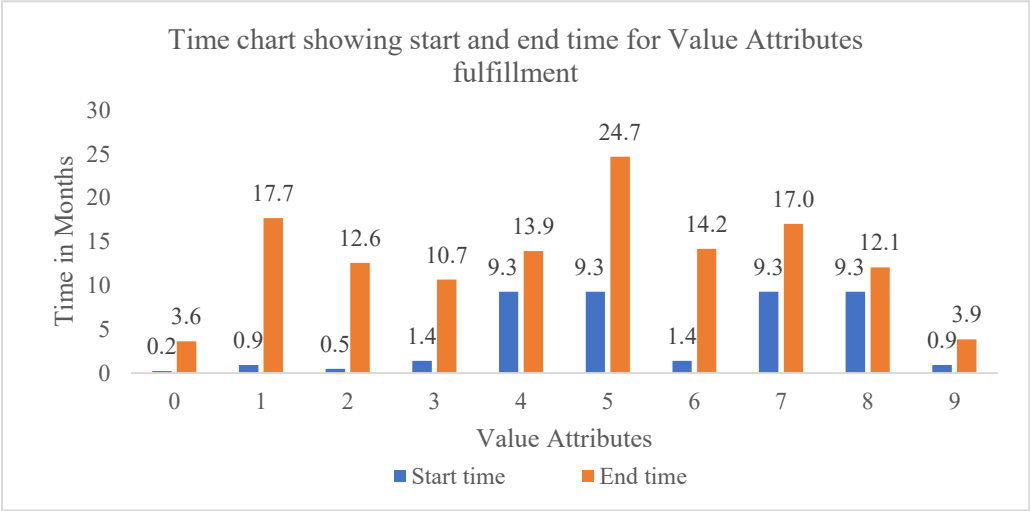


Figure 4-11 Time chart showing the start and end time for fulfillment.

4.4.2 Interpreting results and model applicability

The total design duration for the project spanned 26-27 months, which is in line with the model output. The model results for value fulfillment were compared to actual data and assessed by the project manager. Valuable insights were extracted from these results, as explained earlier. Additionally, as per the project manager, despite this project not being an IPD project, the project team followed best practices for collaboration, as evident in the active engagement of users and other stakeholders and maintaining continuous follow-up with their representatives. This

collaborative approach contributed to a streamlined design process, leading to fewer iterations, as indicated by the model results showcasing minimal drops in value fulfillment. The success of this collaborative nature in mitigating design iterations highlights the importance of engaging stakeholders throughout the project and demonstrates how much such practices can positively impact value attainment.

After testing the model on extreme cases and on the real case study, a comparison of all three cases revealed that the model provides insights into the expected value fulfillment. Although uncertainties and complexities within projects limit accuracy, the model serves as a tool to promote and facilitates value planning, tracking, and discussions during design to achieve higher value attainment. This tool enables proactive planning for value achievement instead of leaving it to the circumstances. By monitoring value, managers can effectively manage it and foster collaboration. Additionally, understanding team dynamics enables faster issue resolution. Therefore, it is important to reflect on project-specific attributes and identify the weights of the influencing factors. This tailored approach enables scenario analysis, allowing for the testing of changing conditions and their impact on fulfillment and the time required to achieve it, compared to the original scenario. Time is critical as it correlates with cost implications, making it particularly significant for project owners.

By demonstrating the applicability of the agent-based model on a specific scenario, this showcases its potential value in decision-making and understanding the complexities and dynamics of the real-world system by predicting specific behavior. In describing simulation tools utilization as management tools in construction, research results suggest introducing these tools for specific-purpose simulation systems rather than general-purpose tools. This approach allows adopters to become comfortable with these tools; they subsequently develop them into more

advanced and sophisticated applications (AbouRizk, 2010). As such, the approach in this research developed a simple simulation tool that serves the purpose intended of providing insights on value fulfillment yet has the potential to be upgraded and developed further once its actual implementation is tested.

4.4.3 Model validation and verification

The validation included two parts, the first is validating the conceptual model as it is developed, and the second is validating the computational model after completion, as per Sargent (Sargent, 2010). The conceptual model validation was performed based on Robinson (S Robinson, 2008) suggesting that modelers need to discuss the problem with their clients to confirm they understand the problem situation. For this research, the conceptual model was discussed with the project manager on the case study project, and their insights were incorporated into the model and in the analysis of the results.

Computational model validation usually involves comparing the model's outputs or predictions to real-world data or observations. As discussed earlier, the model results were compared to the actual progress and discussed with the project manager. The model was validated at certain points in time. While the authors had fewer numerical data points that reflect the progress of value fulfillment than what was provided from the model, the discussion with the project managers confirmed the logic of the results as it was observed in real life. This expert judgement, along with validating it with peer review from 5 design experts, constitutes the model validation. This method is called face validation, where experts in the domain review the model and confirm that its structure, logic, and assumptions align with their knowledge and understanding of the system being studied (Sargent, 2010). For the model verification, two extreme scenarios were suggested as mentioned earlier. The two scenarios consisted of 'scenario 1' with high values,

utilizing high interest and high knowledge for all team members, and ‘scenario 2’ with low values, assigning low interest and low knowledge to all team members. The low scenario yielded zero value fulfillment, and the model kept running since value fulfillment never reached 100 to halt the simulation. Conversely, the high-value scenario exhibited a linear increase and fulfillment in value attributes. The extreme scenarios test and tracing the changes in variables ensured that the model components were working as expected, thus verifying the model (Sargent, 2013).

4.4.4 Limitations and future work

Frameworks and tools that require a considerable amount of effort tend to be overlooked by project managers. Additionally, teams are usually too busy, thus, the buy-in won’t be easy. However, the demonstrated usability of the model in the earlier discussed case study emphasizes its practicality and potential use. This research further offered guidance on implementing the tool or even adopting its key aspects. For example, during the simulation development, specific planning practices were inquired about, which enables project managers to consider these techniques and prioritize following up on value fulfillment during design progress. The authors also tried to encompass the significant factors impacting value fulfillment while ensuring simplicity to enhance the model’s future usability. Nevertheless, the authors acknowledge the model’s sensitivity to certain limitations, which include the following:

- The model is designed to be practical rather than exhaustive, encompassing the major influential factors to offer valuable insights on value fulfillment and timeline. While the model captures these factors, it remains flexible and adaptable, allowing for the inclusion of additional factors as needed. Every project’s unique context may necessitate zooming in on specific other factors. Expanding the analysis with greater detail can yield more precise insights.

- Recognizing the intrinsic subjectivity of value, it is important to acknowledge that frameworks developed for value management may also possess a degree of subjectivity. However, rather than considering this subjectivity as a drawback, it should be embraced as an opportunity. This subjectivity aspect allows flexibility and adaptability in tailoring value management approaches to unique project contexts and stakeholder perspectives.
- The level of detail was limited for simplifications purposes, but it remains open to expansion to enhance its accuracy. The aim was to provide a concise yet useful model that provides insight on where the project is heading in terms of value fulfillment and alignment. However, expanding the analysis with greater detail can yield more precise insights. For example, one factor considered was influence/power, typically associate with formal authority within the project's hierarchy. However, other sources of power are found on projects and may impact managing value. Bourne and Walker (Bourne & Walker, 2005) highlighted (a) personal power derived from human relationships, where personality traits play a role in granting people their influence within their surrounding by being likeable or admired, or through their expertise and knowledge, and (b) political power linked to the control over the decision-making process and/or coalitions. Incorporating these sources of power into the model would increase its accuracy. Similarly, capturing stakeholder's engagement in a more precise manner would add another layer of depth to the model's results.
- For model verification, while the authors performed sensitivity analysis to check the model logic, it was limited to few parameters. The interconnectedness of the different factors in the model made it complex to check for sensitivity analysis in an extended manner.

For future work, the authors intend to use the ABM tool in scenario analysis and experimenting on how things change when conditions are different (example the type of project delivery). This

will be associate with incorporating Fuzzy into the agent-based model based on the study by Raoufi and Robinson Fayek (Raoufi & Robinson Fayek, 2018). In this research, we had two levels for each of the influential factors to simplify the model. Future work will incorporate a more accurate reflection of the factors by having diversified level. Membership function could then be incorporated to translate these diverse levels into numeric values using the fuzzy inference system. Additionally, future work can utilize Monte Carlo simulation to generate random numbers for the parameters and variables associated with different delivery approaches, facilitating a comparative analysis of the results.

4.5 CONCLUSIONS

The research aimed to help managers assess expected value fulfillment during project design by understanding the interplay among team characteristics and communication endeavors, project setting, and value attributes. For this purpose, an integrated agent-based simulation tool was developed to provide valuable insights on what to expect in terms of value fulfillment and alignment considering teams behavior and specific project characteristics. The study first specified factors for inclusion in the simulation, selecting key aspects influencing value alignment and management. Mathematical models were developed to weigh the impact of these factors on value improvement and alignment. These weights were case-dependent, reflecting project dynamics and delivery approach.

The computational model was then built using AnyLogic simulation software, and iteratively validated with experts in project value optimization. A real-world case study closely resembling the modeled system was selected, providing accurate dynamics and interactions among project agents. The simulation experiment was performed on ten value attributes and 40 members from eight teams. The results revealed patterns and varying slopes in fulfillment rates with

significant variations in the time needed to achieve fulfillment. Drops in value fulfillment were observed, indicating the storming phase of team development. This drop helped teams better understand each other's value perceptions. Dependencies between attributes were evident. Monitoring these dependencies is essential for resolving and fulfilling value attributes effectively. Results of value fulfillment and alignment were used to calibrate and validate the agent-based model, ensuring it accurately represents observed behavior. The tool has the potential to be further developed to consider more factors on a project that impact value fulfillment as assessed by decision-makers or project managers. This tool allows managers to effectively plan, monitor, and intervene in value fulfillment when necessary, enhancing their decision-making capabilities.

The research highlighted the importance of collaboratively planning to translate value propositions into design solutions and dedicating time to check on these efforts regularly. By doing so, the expected value fulfillment on projects would be higher, thereby leading to higher satisfaction among project stakeholders. The suggested tool is part of the value management practices endorsed globally to deliver the best value for projects where associated decisions are audited against a value system shaped by its stakeholders.

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Chapter 5: Advancing Engineering and Architecture Education for Project Value Delivery

This chapter investigates the value concept within academic programs in architecture, engineering, and construction (AEC). The primary research objectives encompass 1) investigating the familiarity and comprehension of the value concept among both students and practitioners, 2) identifying gaps in the teaching of value within AEC education, and 3) proposing essential strategies to overcome these educational shortcomings. To accomplish these objectives, combined qualitative and quantitative approaches were employed. This included administering structured surveys, conducting interviews, and performing statistical analysis on responses from students and practitioners. The chapter introduces a pedagogical framework that encompasses educational content supporting value delivery and having lean principles, design thinking, sustainability, and digital collaborative technologies as the main pillars for this framework. The survey and interviews revealed a major deficiency in students' and practitioners' familiarity with the concept of delivering value on projects and the tools needed to enhance it. Thus, this exploration exposed a knowledge gap within AEC curricula concerning project value. Additionally, the research highlighted inadequate cross-disciplinary engagement and collaboration efforts. Students and practitioners expressed doubts about the relevance of academic projects. Nonetheless, participants acknowledged the importance of promoting a better understanding of the value concept and its associated practices.

5.1 INTRODUCTION

The architecture, engineering, and construction (AEC) industry touches every aspect of people's lives and daily activities. While shaping entire communities, the AEC industry addresses the diverse needs, requirements, and necessities of project users, owners, builders, investors,

designers, regulatory agencies, and—more importantly—society in general. Designers and construction professionals serve a fundamental role in processing these collective requirements by defining, analyzing, and translating explicit and implicit needs into design specifications (Kamara et al., 2002). This goal of fulfilling the requirements of different stakeholders represents value delivery on construction projects (Barima, 2010). Without an appropriate and early understanding of stakeholder value on projects, design solutions are less likely to deliver satisfaction and meet stakeholder needs (Whelton, 2004).

Researchers have offered different approaches for improving value delivery on projects, such as value management (Kelly, 2003), integrated project delivery (Matthews & Howell, 2005), and lean principles (Ballard & Howell, 1998), among others. However, the construction industry is still behind in capturing intended expected value by different stakeholders (Laursen & Svejvig, 2016) due to two factors: 1) a lack of profound knowledge regarding the value concept and methods to deliver value on complex projects (Martinsuo et al., 2019) and 2) a lack of training and preparation of future practitioners to apply such methods. While various studies have tackled the first factor (Kliniotou, 2004; Thyssen et al., 2010; X. Zhang et al., 2013), research addressing the second factor, relating to improving education and training of AEC practitioners on value is still behind. In fact, improving the industry is contingent on improving the curricula taught to students who will practice within the AEC domain. Demands to improve environmental, social, and economic value of construction projects have been expressed within the literature (Levitt, 2007). Since conflicting demands of involved parties and the diverse interests of different related sectors adds to the complexity of project delivery, collaboration among multi-disciplinary teams is indispensable (Bjørberg et al., 2015). Research shows that engineering education, in particular, needs to rethink engagement among interdisciplinary teams (Xian & Madhavan, 2014). In fact, the

development of digital web-based technologies helped facilitate design collaboration, and computer supported collaborative design has been an active research area (Shen & Hao, 2007). The research community has also called for new methods for creating, capturing, negotiating, and delivering value in complex uncertain projects (Martinsuo et al., 2019).

Given these deficiencies and the callouts for more research, the research objectives are first to investigate whether AEC education sufficiently prepares students to identify value on projects and improve value delivery, and second, to propose a theoretical framework to improve AEC education's delivery of the value concept to students. Thus, a set of proposed content, strategies, and concepts are identified that help educators in teaching students this concept and the related tools. The overall goal is to improve practitioners' perceptions of construction projects as value-based collaborative endeavors that can satisfy stakeholders' various needs.

5.2 LITERATURE

Investing in the education of future AEC professionals is considered a primary step towards improving the industry's practices and norms. This chapter discusses the different concepts related to achieving higher value on construction projects as addressed in the AEC literature. Additionally, practices and tools that aid the delivery of value on projects are identified and then explored in AEC education literature.

5.2.1 Project value in AEC literature and related concepts

Ensuring the value for money on construction projects has been a major discussion within the international project-management community through the application of value management workshops; clients, designers, and users need to articulate their requirements to be able to deliver value on projects (Green, 1994). In fact, government and industry initiatives seek to maximize value in construction beyond monetary value to encompass customer satisfaction, productivity,

and safety while exceeding expectations of users (Devine-Wright et al., 2003). During our search for value delivery and customer requirements in the AEC literature, and as part of a structured literature review, three major concepts were found to emphasize the value concept at their core and within their guidelines: lean philosophy, design thinking, and sustainability. Additionally, the literature indicates that the value delivery concept can be examined using different terminologies, including: voice of the customer (Found & Harrison, 2012), user and stakeholders' satisfaction (Pirozzi, 2019), and benefits realization (Laursen & Svejvig, 2016). These concepts and terminologies and their relation to value are discussed in the following paragraphs.

The voice of the customer, which is a core concept in marketing science and product development, is perceived as essential for satisfying the construction industry's requirements and has been incorporated into design using quality function deployment (Kamara et al., 2002). According to Mallon & Mulligan (1993), customers are the parties impacted by a product; they are the entities receiving an output from another entity to build upon or use. This makes every participant in a construction project a recipient of another person's work and therefore a customer which needs to have their "voice" effectively captured. Stakeholders to a project are defined as "participants in the human process of joint value creation", thus, each stakeholder can bring value, which could be negative or positive to the project (Pirozzi, 2019). Therefore, managing value on construction projects is deemed essential to achieve stakeholders' satisfaction.

One fundamental lean thinking principle is delivering value by specifying what best suits customers' needs (Liker, 2004). According to Ballard and Howell (1998, p. 5), "value is generated through a negotiation process between customer ends and means." Womack and Jones (1996, p.6) described value as "only meaningful when expressed in terms of a specific product (a good or a service, and often both at once) which meets the customer's needs at a specific price at a specific

time." This flow of work and value generation to the end customer is described as a guiding principle in lean theory, which expands on the transformation view (L. Koskela, 2000). In a lean project delivery system, stakeholders' purposes and values are defined in the project definition phase, and coherence between this phase and the lean design phase is actualized through the alignment of values, concepts, and criteria (Ballard & Howell, 2003).

Another approach that focuses on value for customers is design thinking where design in engineering and architecture is envisioned as a thoughtful and complex cognitive process that requires creative and innovative solutions to meet project needs and requirements while satisfying a set of constraints (Dym et al., 2005). As designers face ambiguity and uncertainty during design, they have to make decisions, think as part of a team in a social process, and handle iterative loops of "divergent-convergent thinking" (Dym et al., 2005). Accordingly, the design thinking approach proposes five modes for the design process: 1) empathize, 2) define, 3) ideate, 4) prototype, and 5) test (Plattner, 2010). These stages help in solving challenges, and one challenge on construction projects is creating value for the customer by understanding their needs.

Sustainability is another approach that relates to the value concept. It is concerned with three factors said to occupy a place of core value within projects: social value (e.g., health and safety, relationships with the community), environmental value (e.g., sustainable sites, energy consumption, resource depletion), and economic value (e.g., profitability, technical performance) (Bae & Kim, 2008). Therefore, when analyzing how a proposed facility will add value, the environment may be viewed as a customer that is added to the value equation (Horman et al., 2004).

Moreover, research indicated that value generation in the design process can be improved using computer advanced visualization tools (Rischmoller et al., 2006). These tools provide 3D

and 4D digital visualization that help in capturing customer requirements, ensuring construction capability of the production system, and improving coordination in a common multidisciplinary virtual space (Rischmoller et al., 2006). Computer supported collaborative design has been an active research area, and more tools have been introduced to support effective collaboration in highly distributed nature of design teams and complexity of design environment (Shen & Hao, 2007). Collaborative digital technologies are a core requirement for delivering value and advancing architecture and engineering education to cope with changes in the industry.

To investigate whether such approaches comprise part of the pedagogy of AEC education, a list of important related practices has been developed from the literature. This list, shown in Table 5-1, includes the tools and practices that are deemed essential for better delivery of projects in terms of value creation and realization. According to the findings from the academic literature review, existing core practices have not yet been sufficiently investigated, therefore, further efforts to make these practices part of the curricula are needed. Based on the review, major concepts and practices were further investigated via survey questions.

5.2.2 The value concept in architecture education

While architects are typically considered to be the most familiar of the AEC stakeholders with the concept of value, they are often unfamiliar with the terminology itself. Designers do focus on the social, cultural, and ethical impacts of constructed facilities (Bae & Kim, 2008). Schools have been offering programs to prepare architects to be competent as building technologists, managers, and programmers which has made it easier for architects to coordinate projects. Nonetheless, the building industry is rapidly being transformed through the advancement of technology, immense amounts of data and information, and increasingly complex projects. Therefore, more structured techniques are needed to coordinate the needs of various parties and

produce value for them. Programming is now an important feature of architectural practices. “Programming establishes the consideration, the limits, and the possibilities of the design problem” (Peña & Parshall, 2012). Programming has been described as “problem seeking” so that designers can address through their designs the problems discovered during programming. Peña’s programming includes five steps: establishing goals, collecting and analyzing facts, uncovering and testing concepts, determining needs, and then stating the problem. Accordingly, it is an important methodology that architectural students need to learn in order to better address coordinating and negotiating value propositions on projects. Aranda-Mena (2016) described four techniques that need to be incorporated into the professional practice of architectural education: value management, stakeholder management, building information management, and reflective practice. A project briefing exercise is also an important practice by architects that directly affects the realization of project value. Accordingly, an architectural curriculum should be revisited regularly to cater to changing techniques, increased complexity, and intensified patterns of collaboration.

5.2.3 The value concept in engineering education

Cross-disciplinary collaboration in engineering education has long been encouraged. Several studies have discussed characteristics of successful academic collaborations in engineering education (e.g., Borrego & Newswander, 2008). Collaboration is a fundamental skillset for understanding the different perceptions of parties with respect to value. Nonetheless, educational efforts to achieve actual collaboration within the disciplines of the built environment have been described as confined (Holley & Ben Farrow, 2013).

While the value concept is not directly discussed in engineering education, several learning approaches support the concept indirectly and aim to improve the quality of learning and teaching

experiences. Matters associated with social value are commonly discussed. Ravesteijn et al. (2006) discussed the role of engineers in society and highlighted the need to prepare engineers to communicate at the levels of facts, values, and emotions when using technology to address irreversible societal changes. Trevelyan & Williams (2019) proposed procedures in which engineering educators can enhance a student's knowledge about engineering value creation and points to a literature gap in the philosophical foundations of engineering and in the understanding of engineering value creation. Finally, with the rise of value-driven design (VDD), researchers have begun to call for teaching value models that emphasize the concept of trade-off in value delivery. Bertoni (2020) presented an approach that teaches university students about VDD. While the research provided a solid foundation towards the common goal of understanding value on projects and methods to enhance it, "broader initiatives for teaching value-driven design, going beyond the introduction of a single activity in the frame of a course" are needed (Bertoni 2020, p.18). Moreover, the authors examined syllabi from the AEC curricula by inserting into google search keywords like engineering courses, syllabus, value delivery, and lean construction. Limited results popped out revealing courses from various universities. The authors noticed that few mention value delivery and maximizing value for project participants as part of the lean courses. This leads us to the anticipated benefits of putting together the relevant value topics and content that need to be included in the curricula to overcome this gap.

Overall, academic publications were found to be scarce and not well structured with respect to the value concept. Although lean theory focuses on improving productivity and outcomes, the concept of delivering value is also foundational to lean philosophy. The importance of lean concepts in engineering and architecture curricula is still insufficiently acknowledged. It is important to provide the necessary knowledge and tools for delivering value on construction

projects. Alves et al. (2012) found that one challenge facing lean construction practitioners and educators is to have both parties work together on the adaptation of concepts and not merely the tools connected to lean construction. Another challenge they noted is involving people in meaningful learning experiences to avoid turning lean construction into a passing "fad." Additionally, lean is primarily part of graduate programs at universities; thus, not all engineering/architecture students are exposed to its philosophy. Furthermore, design thinking is often included as part of workshops and optional professional development sessions; in other words, not all graduating students experience it before they find their way into practice.

Dym et al. (2005) recommended that faculty and administrators focus more on advanced training on design within engineering education. Regarding sustainability, life cycle cost analysis is taught but not in terms of the value needed on projects. Kliniotou (2004) worked with ten industry collaborators to establish a value approach to identifying and monitoring value achieved on projects beyond the value management approach. Kliniotou called for teaching similar approaches in engineering programs to promote an alternative way of thinking and communicating the value concept within multidisciplinary teams. Trevelyan & Williams (2019) mentioned that exploring the literature on engineering value creation in business, engineering, and engineering education publications revealed few empirical studies on the subject, which indicates that the "means by which engineers contribute value is unclear." Accordingly, several researchers have noted the importance of teaching value and training students about methods to manage value on projects. Findings from the present study echo these appeals and suggest needed methods and content to support a combined methodology for teaching value holistically, rather than as fragmented concepts.

The construction industry is undergoing rapid transformations. Sustainability measures are being enforced in a number of countries, and technological advancement with artificial intelligence is changing how people perceive and manage projects; thus, integration and cross-disciplinary action are needed more than ever. The education sector needs to keep pace with these changes and prepare students to become active participants in the creation of successful value-based projects. Accordingly, the survey study intends to answer the following: 1) Do AEC programs provide sufficient knowledge about important concepts, including collaboration, related to improving value delivery on projects?, 2) Do participants recognize the different practices and dynamics on projects that affect delivering better value on projects?, and 3) Do practitioners and academics support the importance of incorporating the concept of delivering value into the AEC curricula?

5.3 METHODOLOGY

The research methodology used to develop the proposed framework is based on the design science research (DSR) approach. DSR proposes an artifact that solves a certain problem in a specific field or context through three cycles: the relevance cycle where problems and opportunities are explored in the application environment, the rigor cycle where researchers ground the topic and explore state-of-art for existing solutions to go beyond them, and the design cycle in which the artifact is built and evaluated (Hevner 2007). This research comprised four steps with corresponding tasks.

1) First, to identify the problem and the gap, the AEC literature was reviewed to identify existing factors and approaches that enable or inhibit value delivery, and then assessed to identify how many of these concepts and approaches are discussed and promoted in education literature and respective publications. A structured literature review was thus conducted to find relevant concepts and tools in research studies and publications that improve value on projects. The first

step was to select a number of directly related keywords based on value definition. Examining the best terminologies to describe value in construction, Barima (2010) suggested goals, needs, and standards as top important items for which their fulfillment describes value. The study adds that a comprehensive value approach needs to consider key stakeholders' perspective. Value in construction is integral in the Lean TFV theory – transformation, flow, and value, where production or construction is a "process where value for the customers is created by fulfilling their requirements" (Koskela, 2000, p.89). Consequently, the search included the following: 'value delivery', 'customer requirements', 'stakeholders needs', 'generating value on projects' and 'value on construction projects. Second, we inserted these keywords into different databases such as Scopus and google scholar. We also explored conference proceedings related to lean construction such as the International Group of Lean Construction, since one of the themes in this conference is value delivery. From the search result, we screened the studies and filtered out the most relevant papers by skimming through the abstracts and content. The inclusion criteria were to have studies that discuss the value concept and how to improve value on projects (value approaches, frameworks, tools, related concepts, etc.). By comparing and contrasting the papers' content, the authors checked for patterns and common subtopics, then categorized papers based on themes within the general topic of value. In other words, by cross comparing the studies, three terminologies were found directly relevant to the value topic and three sub-themes were core to the discussion as explained earlier in the literature section. The terminologies were: voice of the customer, benefits realization, and user satisfaction. The sub-themes were: Lean philosophy, design thinking, and sustainability. Additionally, the search resulted in relevant practices and tools such as value management and other approaches as indicated in Table 5-1.

2) Second, to further investigate the gap and develop the solution, better understanding of the problem was needed. Consequently, based on the concepts and tools identified from the literature, a structured survey and semi-structured interviews were prepared and implemented to collect views about the value concept from different architecture and engineering students of diverse backgrounds and countries. 3) Third, statistical analysis was performed, yielding quantitative and qualitative results. 4) Finally, based on the findings from the statistical analysis, content suggestions and directions were identified for a pedagogical framework supporting value understanding in AEC education. The practical implementation and testing of the proposed framework are left for a future study.

Table 5-1 Core practices for enhancing value on projects as seen in the general AEC and academic literature.

Essential core practices	
• Collaboration and teamwork	• Technologies supporting innovation
• Engagement with different stakeholders	• Value management
• Cross-disciplinary coordination	• Quality function deployment (QFD) and total quality management (TQM)
• Integrated design and construction	• Target value design (TVD)
• Contract type (e.g., relational & performance-based contracts)	• Set-based design
• Technologies supporting collaboration / building information modelling (BIM)	• Design management tools (creative workshops) for user involvement to aid communication

5.3.1 Survey Development

For the online survey, the research targeted the audience with a background in AEC education. It was preferable that they also have practical professional experience in the mentioned domains. There was no restriction on participants' age or gender. The researchers sought people from diverse backgrounds and diverse cultures. Given that the survey specifically considered AEC education, participants with no related professional background were excluded. Participants' details and demographic information were collected from the background section (section 1) of

the survey. The approach followed in this research resembled the methodology in Zhang and El-Gohary (2016). The literature worked as a theoretical source and informed the development of three out of five sections in the survey (Figure 5-2 in the discussion section elaborates on this connection). The survey was utilized as an empirical source for establishing the need for the proposed framework. The survey design and development process were iterative and collaborative, where four experienced AEC faculty members were consulted. The selected AEC faculty members are experienced in teaching lean construction and have discussed the topic of delivering value in their classes. Additionally, pilot testing was conducted with engineering and architecture professionals as test participants to check the comprehensibility and quality of questions. After the final revision and approval among the research team, the survey got the ethics approval, and it was distributed on social media platforms and through emails for a period of four months. The survey distribution followed a network sampling approach, where contacted individuals were asked to share the survey with colleagues from their social circle. According to the American Psychological Association, this approach helps members recruit their peers to participate in a research (APA, 2023). This helped in achieving a randomized sampling to collect as many views from different backgrounds as possible.

The survey consisted of five parts. Part 1 collected participants' background information, including details of their current job role, their degrees and certifications earned in AEC domains, and the years of experience in the AEC industry (see Table 5-2 in Results). Part 2 asked participants to reflect on their formal education by rating their agreement with the offered statements that discuss academic approaches and courses outcomes. The rating was based on a scale from 1 to 7, where 1 = "Strongly Disagree," 4 = "Neutral," and 7 = "Strongly Agree." Part 3 was concerned with evaluating the engagement of students with different disciplines and their recognition of the

importance of integration on projects. Part 4 presented a set of expressions related to delivering value on projects and asks participants to evaluate them as a way for knowledge testing (statements can be found in Table 5-5). The discussed matters provide a glimpse into how participants think of the design process and the respective requirements on construction projects. Based on these statements, the definition of project value was provided, and participants were asked if they had heard of this concept and related methods. Finally, while the survey aimed at evaluating the importance of incorporating the concept of project value into curricula, the survey closed logically with a section that reflected on students' and practitioners' interest in learning more about the concept of value. This final section included an open-ended question so participants could share their viewpoint on important aspects that need to be included in academia to improve engineering and architectural practice.

5.3.2 Statistical analysis

Survey responses were first collected into a central repository (a spreadsheet). Then, data was analyzed by identifying correlations between the aggregated data and performing statistical analysis using Python programming language. Different analytics libraries (NumPy, SciPy, and matplotlib) were used to perform the statistical tests. Additionally, hypotheses from the research questions were identified and tested using statistical analysis of participants' responses. For data reliability, the Cronbach's Alpha coefficient was used on the survey items in different sections. It helped assess the internal consistency of the items to represent acceptable results.

5.3.3 Interviews

In addition to the survey, four semi-structured interviews were conducted with practitioners who had an architectural background. The main purpose of these interviews was to collect a deeper understanding of designers' viewpoints regarding the concept of value and to allow them to freely

share their experiences with the design process as well as difficulties associated with it. The goal was to understand existing approaches used by designers to realize value. Architects were selected to be the focus group for these interviews because their role is important for generating the early value discussions and because their work and decisions affect every other engineering and construction discipline on projects; therefore, understanding their perspective on design and delivering higher value through design will be of help for this study.

5.4 RESULTS AND DISCUSSION

The survey mainly investigated two important fields: 1) the AEC education field, where questions mainly addressed the curricula or courses taken during the engineering or architectural degree, and such questions started with "formal education" and "during my course work", and 2) the participants' field of knowledge, where indirect questions that relate to the concept of value were discussed. These questions addressed issues related to owners, stakeholders, rework, conflicts, and requirements on projects. Parts 2 and 3 of the survey are concerned with AEC education. Part 4 is concerned with the field of knowledge. The results obtained from these sections are explained as follows.

5.4.1 Part 1: Participants' demographic data

The total number of participants recorded was 112, among which 72 participants submitted full responses, accounting for a 64.2% completion rate. The response rate, however, cannot be specified, as the approach was open and utilized the network approach; therefore, the total number of AEC students and practitioners that received the survey could not be identified. As for the 72 completed responses, Table 5-2 (a) presents participants' current job roles (at time of survey), Table 5-2 (b) their highest degree achieved, and Table 5-2 (c) presents their years of experience in AEC. Countries that participants had earned their degree(s) in included Australia, Brazil, Canada,

Chile, China, Egypt, India, Iran, Lebanon, Malaysia, Nigeria, South Korea, Spain, UAE, UK, and USA.

Table 5-2 Participants' demographic information: (a) Roles; (b) Highest degree earned; (c) Years of AEC experience.

(a) Job role (at time of survey)	No. of participants	(b) Highest degree	No. of participants	(c) Years of experience	No. of participants
Architecture educator, professor	2	Associate Degree	1	< 0.5	5 (~7%)
Engineer educator, professor	10	B.A.	14	0.5–1	7 (~10%)
Licensed architect	3	Masters	38	1–3	16 (~22%)
Licensed engineer	25	Ph.D.	19	3–5	12 (~17%)
Researcher	2			5–10	11 (~15%)
Student	30			>10	16 (~22%)
				Not applicable	5 (~7%)

5.4.2 Part 2: Value concepts and tools in AEC curricula

When talking about value, and as reflected in the literature review, different concepts and practices exist that enhance value delivery on projects (Laursen & Svejvig, 2016). Three items – sustainability concepts, enabling technologies, and innovation and creativity – were incorporated into Part 2 of the survey, which comprised five statements investigating AEC curricula for which participants specify their level of agreement on a Likert scale of 1–7. Specifically, the questions inquired whether AEC education provides sufficient knowledge about the social, environmental, and economic (SEE) requirements on projects, which are known as the three pillars of sustainability. The questions also asked whether AEC education teaches students about the impact of constructed facilities on human life and the social aspects of communities surrounding those projects (social needs). For both *Innovation/creativity* and *Enabling technologies*, this study investigated whether formal AEC education gives students strong skills to enhance creativity and innovative thinking processes on the one hand (creativity) and if it provides students with sufficient technological advancements and tools to work collaboratively in the industry, for instance building

information modelling (BIM), on the other hand (techcollab). The fifth question was related to the academic projects that students are engaged in and whether these were a good representation of real-life projects (realrepresentation). A box plot was generated for responses to the five questions investigating the AEC education and is presented in Figure 5-1. The one-sample T-test was performed to check the significance level of each question; the results are shown in Table 5-3.

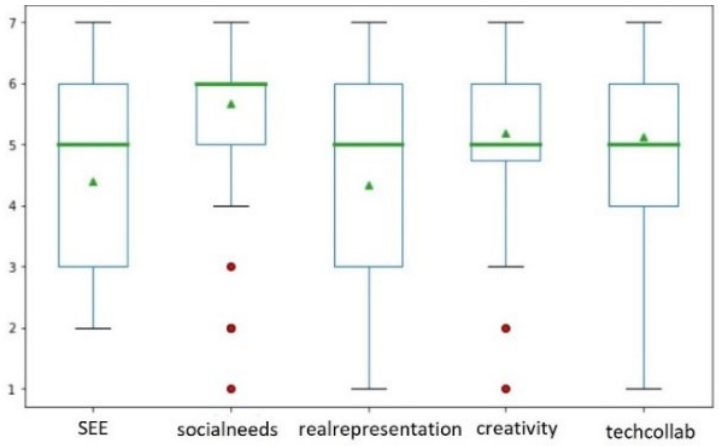

Figure 5-1 Boxplots for the five questions of Part 2 addressing the value concept and related tools in AEC education.

Table 5-3 Means (μ), standard deviations (α), and p-values for survey section 2.

AEC education	**μ**	**α**	***f*-value**
Provides sufficient knowledge about social, environmental, and economic requirements	4.40	1.52	0.01
Lacks teaching the impact on human life and social needs	5.67	1.21	1.68×10^{-18}
Includes projects that are good representations of real life	4.35	1.57	0.03
Enhances creativity and innovation	5.19	1.32	3.12×10^{-11}
Provides technology and tools for collaboration	5.13	1.47	5.11×10^{-09}

All *p*-values are statistically significant at the 95th confidence level, implying that participants indicated their agreement with the five items in the AEC curricula where current programs enhance creativity and provide technological tools for collaboration yet lack the courses that teach impact of the built environment on human life and social needs (this is related to the

design thinking approach). Additionally, variation occurred among participants with respect to having sufficient knowledge about the triple pillars of sustainability, which are environmental, economic, and social requirements. This variation is also observable for item 3 regarding academic projects being good representations of real-life projects. The average value was 4.35, which is closest to 4 on the Likert scale indicating a neutral answer, neither agreeing nor disagreeing. This reflects the doubt held by students and practitioners about the relevance of projects they are given during their years of study.

5.4.3 Part 3: Multidisciplinary engagement and collaboration

Part 3 of the survey was concerned with investigating current practices in AEC education that are relatable to delivering higher value of projects. Part 3 questions addressed four major, critical practices that need to be strengthened in academia for better practices: 1) engaging with teams from different disciplines on common projects, 2) learning the importance of collaborating with different engineering disciplines to achieve common goals on projects, 3) learning the importance and principles of integration on construction projects, and 4) involving members such as owners/clients or practitioners from organizations on the jury or panel instead of having faculty members only. The four practices were obtained from literature as per table 5-1 (first four practices identified). Participants were asked to share the frequency of these practices during their course work and project. The scale was 1–7 as follows: 1 = “Never, 2 = “Very Rarely,” 3 = “Rarely,” 4 = “Occasionally,” 5 = “Frequently,” 6 = “Very Frequently,” and 7 = ”Always.” Table 5-4 presents the mean, standard deviation, and *p*-value for each AEC practice.

Table 5-4 Statistical results of AEC education practices regarding collaboration with different disciplines

AEC education:	**μ**	**α**	***f*-Value**
1- During course work, I was engaged with teams from different disciplines on common projects.	3.91	1.71	0.34
2- During my academic studies, I had courses/workshops that introduced me to the importance of collaborating with different engineering disciplines to achieve common goals on projects (e.g., courses, seminars or workshops, or common activities)	3.61	1.56	0.02
3- During my course work, I was taught about the importance and principles of *integration* on construction projects	4.40	1.54	0.02
4- During my engineering capstone projects (Final year project) or architectural projects, the panel or the jury members included not only faculty members but also owners/clients, practitioners from organizations, and so on (assess based on the approximate % of projects that involved extended parties other than faculty)	2.61	1.65	3.7×10^{-10}

Participants indicated that of the listed critical practices, only one was performed "more often" (score greater than 4). Responses indicated that being taught about the importance and the principles of integration on construction projects is occasionally to almost frequently present during course work, with a mean of 4.40 (statistically significant). Indeed, AEC academia now teaches the importance of involving the contractor early in the design process and involving the end-users to capture their needs and requirements. When asked about the collaboration with different engineering disciplines, participants recorded that they rarely to occasionally ($\mu = 3.61$, statistically significant) have courses to introduce the importance of achieving common goals on projects through collaboration. No clear outcome was revealed when asked about the actual engagement with teams from different disciplines, and results were not statistically significant. This indicates that engineering/architecture students need to work more on common projects. Participants agreed that it is rare to have non-faculty members on academic project panels or juries. The mean score for this question was 2.61, and results were statistically significant. While such

practice is not yet common, the act of including practitioners from different construction organizations or project developers with a different perspective than academia is deemed essential and yet still missing. Overall, regarding collaboration, integration, and working with different disciplines, none of the four questions was frequently practiced or has a mean >= 5, indicating that these critical practices are still behind in academia.

5.4.4 Part 4: Knowledge testing - Delivering value on construction projects.

Part 4 of the survey was designed to solicit information about participants' knowledge and perceptions of the different practices used during design and construction and relatable to lean concepts. Participants were asked to evaluate seven statements listed in Table 5-5, concerning projects' value, owners' involvement, architects/engineers' roles, and conflicting requirements on projects. Participants indicated their level of agreement with the seven statements using a 7-point Likert scale, where 1 = "Strongly Disagree," 2 = "Disagree," 3 = "Slightly Disagree," 4 = "Neutral," 5 = "Slightly Agree," 6 = "Agree," and 7 = "Strongly Agree." Table 5-6 presents the mean, standard deviation, and *p*-value of the responses.

Table 5-5 The nine statements participants were asked to evaluate.

Number	Statement
1	Before design starts, if the proper questions are asked by the designer, an owner will be able to express what they value on projects, their needs, and their requirements.
2	I believe some requirements are implicit, and it is the architects'/engineers' role to make them explicit and uncover these hidden needs during the building design process.
3	I believe that the satisfaction of the owner is the primary objective of any project.
4	I believe the satisfaction of all major stakeholders is NOT a significant issue.
5	I believe rework on projects is mainly due to the lack of sharing of information among different designers and engineers in due course (appropriate time) during early design stages.
6	I believe conflicts are mainly due to improper management of contradicting goals.
7	I believe that during the construction phase, new requirements would be revealed with the engagement of more stakeholders and some other requirements would be changed.

Table 5-6 Analysis of all responses to the nine survey statements

Statement	Mean (μ)	Stand. dev. (α)	*p*-value
1 – Proper questions	6.05	1.124	8.42E-25
2 – Hidden needs	5.931	1.202	8.57E-22
3 – Owner satisfaction	5.236	1.543	1.37E-09
4 – Stakeholder satisfaction	2.528	1.491	1.68E-12
5 – Lack of sharing during design	5.722	1.258	2.25E-18
6 – Conflicting goals	5.431	1.351	1.26E-13
7 – Changing requirements	5.806	1.016	*3.93E-24*

5.4.4.1 Hidden needs

Statements 1 and 2 expressed the importance of questions by designers to encourage owners' engagement in expressing their needs, their requirements, and what they value on a project, bearing in mind that some of these requirements are implicit. Responses had a mean of about 6 and recorded statistically significant results indicating agreement of all participants with Statements 1 and 2. This suggests that project value requires joint effort to reveal hidden needs. In fact, one of the important roles of designers is to uncover hidden needs in order to avoid future conflicts or client dissatisfaction on projects. The Design Thinking Bootcamp guide (Plattner, 2010) that supports design thinking practices from the Stanford d. school says, "Engaging with people directly reveals a tremendous amount about the way they think and the values they hold. Sometimes these thoughts and values are not obvious to the people who hold them. A deep engagement can surprise both the designer and the designee by the unanticipated insights that are revealed." As such, one important practice during design from the early start is having the proper discussions where the right questions are asked and answered.

5.4.4.2 Owner and stakeholder satisfaction

Project value is about both fulfilling the owner's goals, desires, and standards and achieving end-users', suppliers, and project teams' satisfaction. To further investigate whether owner satisfaction

as well as stakeholder satisfaction are thought to be significant on projects, participants were asked to evaluate Statements 3 and 4. In reply to owners' satisfaction being the primary objective on projects, participants recorded a statistically significant score of 5.23 ("Slightly Agree"). This score might reflect that participants think owner satisfaction is not the primary objective on projects, even if they think it is one of the main objectives. Responses to Statement 4 endorsed those to Statement 3: asking whether "the satisfaction of all major stakeholders is NOT a significant issue" returned a mean score of 2.5 ("Disagree"), demonstrating that participants actually understand the importance of attaining satisfaction for end-users, suppliers, and project teams as part of achieving a successful project.

5.4.4.3 Trade-offs

Value on projects is dynamic where it changes because of proliferation of information over the project duration, and it involves trade-offs when contradicting goals are found. Statements 5–7 in Part 4 of the survey concerned value characteristics that need to be understood on projects because they describe actions that can lead to rework and conflict. Statement 5 asked participants if they believe rework on projects is mainly due to lack of timely sharing of information among designers during early design stages. Statement 6 asked if they think conflicts are mainly due to improper management of the contradicting goals of people involved on projects. Statement 7 asked if participants agree that new requirements could be revealed, and other requirements would change with the engagement of more stakeholders during construction. For all three statements, the mean was statistically significant and ranged from 5.4 to 5.8, or "Slightly Agree" to "Agree." While several reasons for rework and conflicts on projects exist, it was important to highlight that information sharing in a timely manner and resolving contradictions on projects are among the critical aspects for avoiding much of the rework and conflicts on projects. Finally, the survey was

also designed to seek participants' opinion, based on their experience, whether during construction new requirements could be revealed and some other requirements would change with the engagement of new stakeholders. Accordingly, embedded within these statements is the emphasis that contacting these stakeholders early on and having discussions with them would minimize the effect of such changes.

5.4.4.4 Recognizing value terminology and methods

After assessing Statements 1–7, participants were provided with the definition of value on projects: "Based on the above, *project value* is defined as the collective needs, requirements, and desires of different stakeholders that are negotiated and agreed on during project development. Project value represents the guiding principles for achieving successful projects." Participants were then asked to state whether they were familiar with the term *identifying value on projects* and methods for improving value delivery. Results show that 24% of participants recorded that they have either not heard the term or do not understand what value on projects is, 45% have general to basic knowledge of the term, and only 31% have good knowledge of the term. Regarding the methods for improving delivery of value on projects, these percentages are even lower, where only 26% have good knowledge. Results reflect a major problem: 59% of people from industry and academia may have general to no knowledge of methods for improving value delivery. It is possible that even people with good knowledge (26%) are mostly not applying such methods, if the majority of the teams on their projects lack sufficient knowledge to support delivering value on projects. Additionally, when asked about the means for acquiring this knowledge, the majority of participants responded that they took a course (mainly a lean course) introducing them to the concept of value and/or related methods. Few indicated that knowledge about the concepts was acquired from practical experience.

5.4.5 Part 5: Students' and practitioners' interest in the value concept

In general, participants collectively indicated the need to 1) include sessions to engage students (*Engaging students*) from different disciplines to discuss what is important for them on a project (mean = 6.11, SD = 0.94); 2) be involved in mock-up negotiations (*Mock-up negotiations*) to understand trade-offs on construction projects (mean = 6.13, SD = 0.81); and 3) learn about the concept of delivering value (*Value delivery concept*) on projects (mean = 6.26, SD = 0.872). While all categories reflected an existing need to learn more about the concept of delivering value on construction projects, a statistical difference between the academic and professional groups was found. Of the academics, 70% said it is "Absolutely important" and the other 30% revealed it is "Very important" to learn about this concept. The professionals were more diverse in agreeing with this matter and less sure about the absolute necessity to learn about it.

The survey concluded with an optional open-ended question that asked participants to share one important aspect they think is needed in AEC academia to improve the engineering and architecture practice. Twenty-nine responses were received with numerous valuable inputs, which are summarized in Table 5-7.

In general, several educators shared their concern that some practices are only performed once throughout the degree or as one participant labelled it a "one-off exercise." Instead, a more frequent engagement of different disciplines on common projects is needed. One engineering educator with 10–20 years of experience framed collaboration as, "What is often viewed as frustrating differences should be repackaged as beneficial diversity that improves the overall achievement of project value."

A mutual call was recorded for real-life projects engagements to "avoid being abstract based on fantasy art," as one professional engineer stated. There was a repeated request for more

practical involvement during academic years, not only as learners, but also as action makers, to ensure students are aware of the practical conflicts arising on real projects.

Table 5-7 Summary of suggestions for improving AEC academia from the open-ended question.

Job	Suggestions/recommendations
Engineering/ architecture educators	• Enhance multidisciplinary approach in courses. • Understand the work environment through mandatory field training courses yearly. • Integrate academia with practice. • Support knowledge about other engineering disciplines. • Read other disciplines' drawings and documents. • Get input from major organizations so that curricula match industry expectations.
Professionals	• Manage priorities keeping in mind the client and stakeholder requirements. • Select the right team and maintain this team for most projects. • Provide teams with goals and key performance indicators to be achieved. • Boost lean project management throughout project phases (design and construction) • Involve students in real projects to sense the hurdles of coordination and understanding the different value aspects from designers to stakeholders. • Make sure educators of key program courses are practitioners. • Link projects to reality: regulations, environmental constraints, and psychology • Create a curriculum that respects all stakeholders involved on projects and building long-lasting relationships with them. • Advocate for conversations on construction/assembly methods and team dynamics
Students	• Teach students to lead change in their work environment and apply what they learn • Utilize modern technology. • Conduct workshops/seminars with people from the industry/ Involve industry experts on projects. • Arrange common classes to integrate architecture and engineering students. • Engage students in games requiring collaboration between architects and engineers. • Teach engineers basic design tasks and teach architects basic engineering design

5.5 DISCUSSION

Survey results revealed several important aspects about AEC academia. In what follows, we will discuss these aspects and the findings of the research questions identified earlier. To ensure

reliability of the analysis which is based on different sets of data collected from the survey questions, we checked for Cronbach's alpha coefficient. Results yielding to a minimum score of 0.7 were considered "acceptable" as in most social science research and were therefore included. 1) First, with respect to investigating whether AEC programs provide sufficient knowledge about important concepts related to improving value on projects, results showed that participants collectively revealed slight agreement and were sometimes neutral about the fact that concepts are sufficiently offered. Moreover, investigating whether AEC programs provide sufficient collaboration across disciplines (i.e., engagement with different disciplines), results showed participants felt that AEC programs are still weak with respect to collaborative endeavors. Full collaboration on projects will only be made possible when exploiting the potential of current digital collaborative technologies, starting with BIM. Essential practices for interdisciplinary engagement and integration revealed setbacks in collaboration attempts. Accordingly, students are yet to be prepared for the profound transformation needed in the AEC industry, where digital technology will be central. 2) Regarding the research question whether participants recognize the different practices and dynamics on projects that affect delivering value, and based on findings from the knowledge testing section, collaboration section, and concepts and tools offered in AEC curricula section, participants showed that some practices are recognizable yet there is still a need for further learning. 3) Regarding the question "Do practitioners and academics support the importance of incorporating the concept of delivering value into the AEC curricula," results revealed that professionals endorsed including this concept in curricula, but they were more diversified in their agreement with this concept in comparison to academics. Lean courses are already making their way into AEC academic programs, and the concept of value is considered part of lean philosophy. However, more focus on the tools and methods to enhance delivering value on projects is needed.

5) Finally, responses showed that students and practitioners were not satisfied with the quality of projects to which they were exposed, and the request to engage students on actual projects through multiple trainings was highlighted by participants in the open-ended question.

Regarding the four semi-structured interviews with practitioners who had an architectural background, interviewees perceived design as a creative process where the requirements and needs are typically discussed during the course of design, and alternatives are provided that include out-of-the-box thinking. However, interviewees commonly described the design process as complex and challenging for multiple reasons: clients might not be able to provide accurate information; clients' needs can be endless and often require unique, "fabulous" designs are requested within a limited time and budget; dealing with design problems improves with experience; and a considerable number of updates and changes are needed to explore multiple options. When asked about hurdles faced by designers when recognizing the needs of different stakeholders, interviewees' responses showed concerns about coordinating and balancing stakeholder needs, revealed a substantial gap between design and construction, and identified deficiencies in collaboration among the full, extended list of stakeholders. As for coordinating with different disciplines, interviewees noted hurdles such as "siloed" thinking in each discipline and misconceptions about one another's jobs. One interviewee stressed the importance of value being related to client satisfaction and that "all people are clients [on] public projects." For improving value on projects, interviewees recommended collaboration, transparency, resolving issues together rather than struggling alone, "breaking the ice," and focusing on social aspects among other approaches. Finally, with respect to academic exposure, interviewees suggested that courses related to psychological/social aspects, dealing effectively with customers' needs, and project management approaches should be included in architectural curricula. In general, interviewees

confirmed what both the literature and the survey revealed about the gap in academia with regards to understanding the value concept and the approaches to improve value delivery on projects.

Therefore, based on the survey results presented in the discussion above, a pedagogical framework is suggested in this chapter that includes the essential content and practices that need to be highlighted in the AEC education to overcome the aforementioned concerns: value-related concepts insufficiently offered, weak collaboration endeavors across disciplines, inadequate learning of value-related practices, and low quality of projects. Figure 5-2 illustrates the connections between the literature, the survey sections, survey results, and the pedagogical framework and its components. It shows the concepts and practices revealed from the literature that help students and practitioners in understanding and applying the concept of value delivery on projects. The five sections of the survey are also laid out summarizing their aim and what they inquire about. The survey results are also reported in the figure through indicating which table refers to which survey section. Then, the components of the framework are revealed indicating from where their elements were extracted. In summary, the literature informed the development of sections two, three, and four of the survey; the results from these sections revealed, respectively: (a) deficiencies in AEC education regarding the value-related concepts, (b) not enough collaboration endeavors, and (c) the essentials around value delivery are insufficiently understood. The results from section 5 revealed that participants are interested in learning more about the concept which highlighted the need for the framework. In the upcoming section, the framework components are explained.

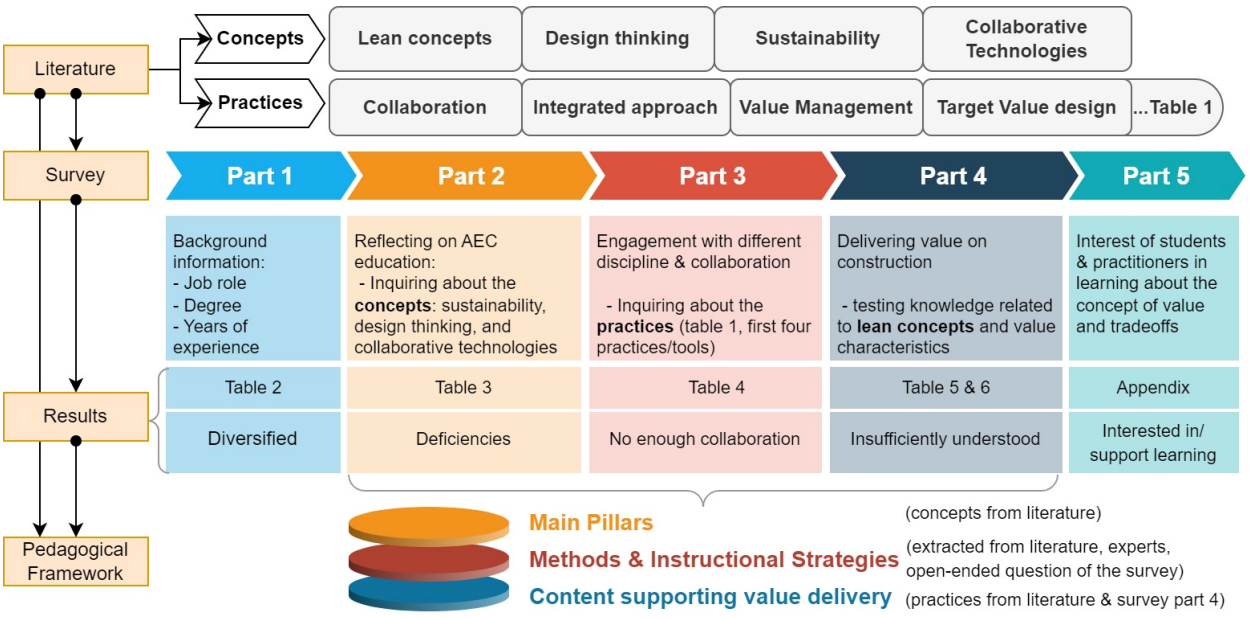

Figure 5-2 Connecting the literature and survey results to the development of the proposed pedagogical framework.

5.6 SUGGESTED PEDAGOGICAL FRAMEWORK

Marzano et al. (2001) identified three requirements for an effective pedagogy: 1) the curriculum design or the content to be taught, 2) the instructional strategies, and 3) the management strategies used. This section focuses on the first two requirements and highlights the main pillars for better value delivery on projects. The third requirement needs a separate in-depth study to provide relevant management strategies. To start with, we suggest the following: 1) dedicate at least one chapter in a course that covers lean concepts to explain the concept of value and its related terminologies (e.g., voice of the customer, user satisfaction, benefits realization), 2) update current existing project-based courses (e.g., design studios, capstone projects) to cover the essentials on coordinating the views of different project stakeholders and considering their needs and requirements on such projects with the use of digital collaborative technologies, and 3) involve students on public projects to focus on the social aspects of construction projects.

Project-oriented models are common in architectural education but less common in engineering education (with the exception of specialized extracurricular projects). Engineering education focuses more on problem sets and computation than on project-based, systems-thinking learning. In fact, this was one of the concerns mentioned in a National Research Council (1995) report. Therefore, in an attempt to push toward more integrated practices, multidisciplinary collaborations should be included in academic projects. Teamwork cooperative learning should be at the core of engineering and architecture education. Digital technologies that foster collaboration and information sharing are indispensable in the shift and advancement needed in AEC education. Offering more practical internships that expose students to such collaborative environment and technologies is essential. Courses that teach BIM should highlight how engineers and architects need to leverage such technologies to enhance collaboration and creativity on projects. Including professors who have experience in engineering or architectural practice is important, as is involving jury members who offer fresh ideas and new perspectives, such as practitioners from different construction organizations. Simulation games were found to be effective in teaching lean concepts and thus are needed to trigger coordination among disciplines for better delivery of value (Rybkowski et al., 2020).

Courses should cover key aspects such as a structured design thinking approach with a focus on delivering value for the different parties, and not merely present this approach in optional workshops. Hands-on learning to support innovation and creativity in presenting solutions and designing prototypes are needed to ensure that future practitioners build the necessary skills to succeed in this complex industry. More focus on constructability is also needed. A standalone course about value and soliciting requirements, needs, and objectives on projects is proposed. In such a course, mock-up negotiations between students of different disciplines and departments can

be conducted. Students need to learn about the characteristics of value (progressive, subjective, and dynamic) and value approaches to manage conflicting needs such as quality function deployment, target value design, and value management workshops. By performing the trade-off needed and managing conflicting requirements, rework and conflicts on projects are minimized.

In summary, the following potential pillars are recommended for understanding and imparting the concept of value: 1) lean philosophy and tools (e.g., set-based design, target value design, Choosing by Advantage method), 2) design thinking, 3) sustainability, and 4) digital collaborative technologies. Figure 5-3 represents the proposed pedagogical framework that includes three components: (1) the pillars that help in understanding the value concept, (2) the suggested instructional strategies, and (3) the specific content and topics that supports value delivery.

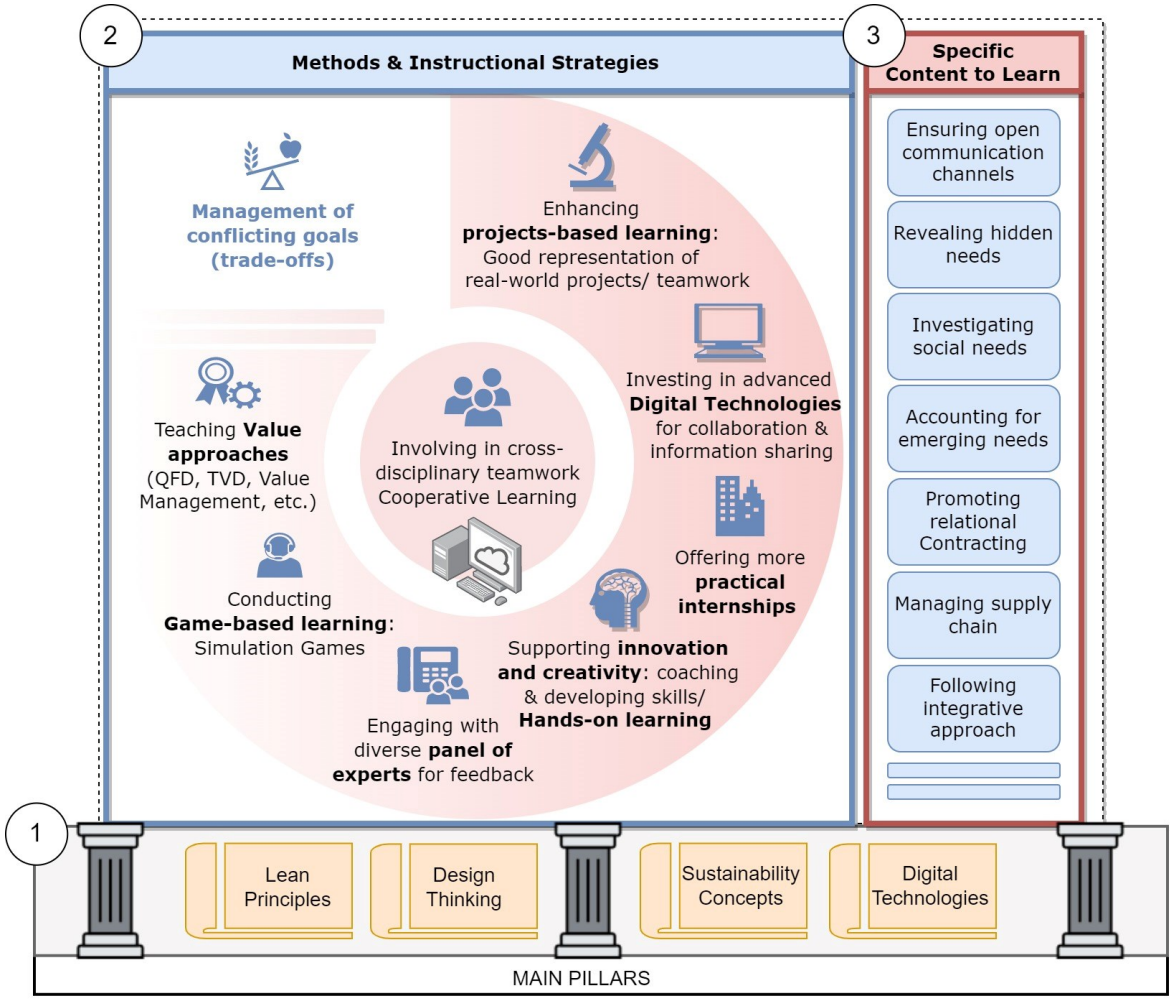

Figure 5-3 Pillars, instructional strategies, and content for improving value on projects through AEC academia.

The four pillars of the pedagogical framework are represented by “books” indicating the necessity of teaching all associated concepts, tools, and philosophies included under these headings. Additionally, several factors supporting the delivery of value on projects need to be highlighted as part of the content suggested to increase the quality of knowledge regarding value. The factors are depicted in Figure 5-3 as part of the framework and elaborated in Table 5-7.

The proposed methods and instructional strategies, factors, and four pillars are the starting point for advancing engineering and architecture education and working towards qualifying practitioners to achieve long-lasting value of construction projects as perceived by their

stakeholders and neighbouring communities. The proposed pedagogical framework is expandable, meaning further methods can be added as needed or desired by researchers, academics, and practitioners. This framework was developed based on the practices excerpted from literature and the insights from a limited number of practitioners surveyed and interviewed. The aim was to provide a foundation for ensuring advancement in AEC education, yet the completeness of the framework can be determined by the wide range of educators and researchers that may build upon it in future research.

Table 5-8 Factors that need to be focused on in academia in support of value delivery.

Factors	Explanation
Open communication channels	Maintaining open communication channels between different disciplines and ensuring each team understands the drawings of the other team
Hidden needs	Asking the right questions to reveal hidden needs and help teams express their opinion
Social needs	Emphasizing social and cultural needs of the society and the people using facilities/projects to ensure their well-being
Emerging needs	Accounting for emerging needs while trying to minimize impact on project costs & time
Relational contracting	Promoting relational contracting instead of traditional transactional contracting
Supply chain management	Advising and managing supply chain integration
Integrative approach	Following integrative approaches with the help of digital collaborative technologies

5.7 CONCLUSIONS

As part of continuous improvement attempts and development required in AEC academic programs, architecture and engineering education was investigated with respect to the concept of delivering better value on construction projects. While lean philosophy has been widely incorporated into the curricula, the concept of value and its associated core practices that promote delivering projects with the satisfactory level of collaboration and value attainment to reduce conflicts, rework, and litigations have yet to be implemented. In this research, a framework that

signifies the pillars, approaches, and content necessary in academic courses and on academic projects was developed to support the guidance on value delivery. In the attempt to do so, a literature review was conducted on publications related to the concept of value in academic literature. The literature review revealed weaknesses and limitations regarding the value concept in terms of teaching this concept in a structured manner. A survey was also conducted and distributed among practitioners and students in AEC disciplines, and four additional interviews were conducted with industry practitioners. The responses confirmed the weaknesses identified from the literature, and the results established the need for a framework. The pillars in the framework, including lean concepts, design thinking methodology, sustainability concepts, and digital collaborative technologies that help in integration endeavors, need to be incorporated into curricula as part of a plan to improve knowledge about value delivery. By providing a clear approach on how to address hidden, social, and conflicting requirements of different stakeholders involved on projects, and by providing the different tools that can help practitioners achieve this, the construction industry would benefit greatly. The proposed pedagogical framework represents a high-level vision rather than specific teaching strategies for AEC programs. Nonetheless, it provides a starting point for revitalizing the AEC education towards value-driven design and construction and a more efficient delivery of projects in practice. This study contributes to the existing body of knowledge by 1) identifying a gap in teaching Value in AEC curricula and 2) suggesting methods for addressing this limitation. Future studies are needed to investigate empirical applications and test strategies that can help transform academic curricula related to engineering and architecture disciplines.

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Chapter 6: Conclusion

6.1 SUMMARY OF THE WORK

The main findings derived from this research are summarized herein.

Chapter 2 proposed sixteen categories for value propositions (with more than 70 value attributes) to be the starting point for managers to identify their customized project-based value list. It also presented the steps that need to be followed for performing trade-offs between conflicting objectives, by presenting value classifications and a set of recommendations. A proposed framework and dashboard design were proposed showing the actions needed to enhance value delivery on projects early on.

Chapter 3 investigated the links between design team communications and project value performance as well as analyzing the evolving dynamics of value and network structures. Data analytics was used to reveal potential correlation between the communication structures of project teams and value fulfillment on projects. Findings revealed that the inherent social dynamics and social network composition can reflect the team's reported level of fulfilling value on projects as such structures affect a team's ability to effectively exchange knowledge and coordinate design tasks. A proposed socio-technical framework is proposed for studying design communication networks and conducting health-checks and filling value scoresheets to measure attainment.

Chapter 4 developed a simulation model as a tool to help project managers in investigating value alignment and fulfillment within the unique context of project settings and team dynamics. The agent-based simulation tool models the interactions between teams and their effect on emergent behavior with respect to value adoption. By inputting relevant data and configuring

different parameters, results from the applied case study showed that the simulation tool can give insight on value fulfillment levels. This would help managers in making value-centric decisions and adopting effective approaches for managing value on their projects.

Chapter 5 investigated the current AEC literature and current practices in academia with respect to teaching the value concept. After identifying the shortcomings, a pedagogical framework was proposed which can be incorporated into the AEC academia to expose students to the concept of improving value on projects using lean philosophy, design thinking process, digital technologies, and sustainability as main pillars. The framework provides content and teaching strategies to achieve this goal.

In general, the fulfillment of the different value categories could not be measured under one single metric. Aggregating the categories will mask the real performance of these different categories. Therefore, the research presented a set of guidelines under various approaches to quantify different categories of value attributes and then proposed a simulation model that focuses on product value by integrating multiple socio-technical influencing factors into the model.

6.2 RESEARCH CONTRIBUTIONS

6.2.1 Academic Contributions

The following are considered among the academic contributions:

First, the research contributes to conceptual clarity of the value concept. By introducing value categories, classifications, and related factors, the study enhances researchers' and practitioners' understanding of the value concept. This clarification enables project managers and stakeholders to have a unified understanding of value, allowing for more effective decision-making within projects.

Second, the research uncovered the link between communication, team dynamics, and value fulfillment. By utilizing a network approach, the research highlights the crucial link between communication and team dynamics in achieving value on projects. The socio-technical perspective shed lights on the importance of effective communication within project teams to optimize value delivery.

Third, the research identified key influencing factors shaping the alignment of value on projects. This insight equips project managers with the necessary knowledge to analyze these factors in their specific project contexts, leading to improved value attainment.

Finally, the research also focused on advancement of academic programs in teaching value delivery and management within the AEC industry. It introduces a value-focused content tailored to introduce students to the concept of value, social dynamics, and effective project management methods. In this way, future practitioners are better prepared to address real-world challenges of completing successful projects beyond their monetary, schedule, and quality aspects, thus making positive impacts in the built environment.

6.2.2 Industrial Contributions

The research's contributions to the industry are explained herein.

First, in relation to objective one, the research has provided practical guidance on the initial steps of identifying value propositions on projects aiming to enhance project outcomes as perceived by the different stakeholders. Accompanying the guided steps, the research presented a generic versatile list of value categories that practitioners can choose from or draw inspiration from.

Additionally, the research identified actions and measures for evaluating value propositions and resolving any conflicts, then proposed using digital dashboards as early warning tools for tracking

any conflicts down the road. The suggested dashboard serves as a conceptual design, outlining the layout, components, and functionalities of the dashboard.

Second, the research led to the development of a socio-technical lean management framework that guides project managers on how to report value propositions progress based on their type: (a) product-value propositions and (b) process-value propositions. For the social aspect, which includes examining people, the communication efforts and interactions between teams is also examined in this framework using Social Network Analysis. The project managers and the team members were able to visualize design communication patterns, identify bottlenecks and possible weaknesses or autonomous individuals, and discuss improvements moving forward. Restructuring based on the obtained communication networks could take place to overcome identified communication flaws. The clustering algorithms helped in identifying communities within teams and in analyzing disconnected teams. In addition, the applicability of the framework was demonstrated in an actual project and recorded praise from the project team about the utilized methods which are replicable on other projects.

Finally, the research led to the development of a simulation tool that integrates multiple factors encompassing team and project characteristics into the planning of value propositions. This tool will facilitate estimating the anticipated time required to fulfill these propositions and enable better planning by adjusting decisions and assessing their impact on design duration. This, in return, reduces rework and minimizes misalignments among teams while enhancing overall satisfaction and design outcome. This deliverable helps in achieving objective 3 set earlier.

In relation to the general industrial contributions mentioned above, we added specific contributions to the two projects we closely collaborated with over the course of two years.

These are explained in Appendix C. The journey of a PhD student lies in the impact and tangible changes they brought about, making a real difference.

6.3 LIMITATIONS

The following limitations were recorded in the studies and in the overall approach of this research:

First, the dashboard presented in Chapter 2 is currently at the design stage and has not been implemented or used in practical application yet. The intended design serves as a proof-of-concept, demonstrating the potential of such a tool in warning about potential conflicts as perceived by managers. However, the actual implementation of the dashboard requires further testing and integration with relevant real-world applications. Refinements will be necessary before they can be effectively used in value-management practices.

Second, in Chapter 3, the correlation found between network structures and value attainment on projects was based on multiple rounds conducted on one case study. While these results could not be generalizable, this research intended to clarify that the link between having well-connected teams and dense networks and achieving higher value exists. Future work could work on covering more case studies and generalizing the results (check future work section for details).

Third, the research emphasizes the importance of involving different stakeholders during design, however, when the authors conducted the social network analysis survey, we could not reach the external stakeholders to collect their input to include them in the network and then in the ABM model.

Fourth, the simulation model presented in Chapter 4 is designed to be effective rather than exhaustive, encompassing the major influential factors to offer valuable insights on value fulfillment and timeline. While the model captures these factors, it remains flexible, allowing for

the inclusion of additional factors as needed. Every project's unique context may necessitate zooming in on specific additional factors.

Fifth, recognizing the intrinsic subjectivity of value, it is important to acknowledge that frameworks developed for value management may also possess a degree of subjectivity. However, rather than considering this subjectivity as a drawback, it should be embraced as an opportunity. This aspect of subjectivity allows for flexibility and adaptability in tailoring value management approaches to unique project contexts and stakeholder perspectives.

Another limitation is that the level of detail for the model was limited for simplifications purposes, but it remains open to expansion to enhance its accuracy. The aim was to provide a concise yet useful model that provides insight on where the project is heading in terms of value fulfillment and alignment. However, expanding the analysis with greater detail can yield more precise insights. For example, one factor considered was influence/power, typically associated with formal authority within the project's hierarchy. However, other sources of power are found on projects and may impact managing value, such as personal power gained from personal traits and political power gained from control over the decision-making process or coalitions. The engagement was represented in the model as a yes-no parameter. This should be changed for an in-depth analysis of the user-engagement contribution and effect on the project.

Finally, the proposed methods and instructional strategies, factors, and four pillars under Chapter 5 were the starting point for advancing engineering and architecture education and working towards qualifying practitioners to achieve long-lasting value of construction projects as perceived by their stakeholders and neighboring communities. The proposed pedagogical framework represents a high-level vision rather than specific teaching strategies for AEC programs. However, the framework is expandable, meaning further methods can be added as

needed or desired by researchers, academics, and practitioners. This framework was developed based on the practices excerpted from literature and the insights from a limited number of practitioners surveyed and interviewed. The aim was to provide a foundation for ensuring advancement in AEC education, yet the completeness of the framework can be determined by the wide range of educators and researchers that may build upon it in future research.

6.4 FUTURE WORK

Future potential research work could be identified from this work, including:

1- Using Monte-Carlo simulation to increase the accuracy of generalizing the results about the link between network structures and value improvements on projects. The work would include generating random network structures and testing which would help in achieving higher value on projects.

2- Expanding the model: the authors intend to use the ABM tool in scenario analysis and experimenting on how things change when conditions are different. This will be associate with incorporating Fuzzy into the agent-based model based on the study by (Raoufi & Robinson Fayek, 2018). In this research, we had two levels for each of the influential factors to simplify the model which is already complex with all the factors included. Future work will incorporate a more accurate reflection of the factors by having diversified level. Membership function could then be incorporated to translate these diverse levels into numeric values using the fuzzy inference system.

3- Working on a value maturity framework that would allow for measuring progress against a certain limit and thus assess value losses on projects.

4- Collaborating with engineering and architectural departments to assess the practicality and effectiveness of the proposed pedagogical framework. The aim is to discuss the possibility of

introducing a course on “Investigating and Managing Social Aspects on Construction Project”, which includes human-centered design topics, social dynamics on projects, improving value delivery, and design thinking strategies, in alignment with the overall principles highlighted in this research.

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Appendix A – Survey for Chapter 3

Section 1: Demographical Information

Name (will not be used/ it will be abbreviated based on your position and kept anonymous):
Company/organization Name: _____
Department Name/Position: _____

Q2. What is your **profession**? If it's not listed, please specify under others:

☐Architect
☐Structural engineer
☐Mechanical engineer
☐Electrical engineer
☐Interior designer
☐Landscape designer
☐Other, please specify: _____
☐Project manager
☐Construction manager
☐Planning engineer
☐Estimating engineer
☐Surveyor

Q3. Your overall **experience** in the construction industry is:

☐Less than 1 year
☐1 to 3 years
☐3 to 5 years
☐5 to 10 years
☐More than 10 years
☐Other, please specify: _____

Section 2: Knowledge exchange and value communication

Here list all the names (& organizations) of the people you communicate with about the following project values:

1. Operational Excellence and efficiency
2. Resilient and constructable design
3. Social responsibility (internal and external stakeholders)
4. Environmental resilience and sustainability (energy, indoor space, material use, construction processes, etc.)

These values are translated into design requirements on the project and their discussion is important for project success.

Please specify the frequency of this communication, the mode of communication (emails, meetings, etc.), and the importance of the input/information exchanged with this person with respect to your work.

Person's name and their organization	Indicate the **frequency** of your communication with this person about the project requirements and agreed design values	Indicate the most frequent **mode** for design value communication with this person.	In general, indicate the **importance** of the communication with this person for your work
1.	☐N/A ☐1. Minimal ☐2. Sometimes ☐3. Frequently ☐4. Very frequently ☐5. Always	☐N/A ☐1. Chats/texts (informal) ☐2. Emails ☐3. Phone calls ☐4. Meetings (in-person or virtual)	☐N/A ☐1. Slightly important ☐2. Important ☐3. Very important ☐4. Extremely Important ☐5. Critical
2.	☐N/A ☐1. Minimal ☐2. Sometimes ☐3. Frequently ☐4. Very frequently ☐5. Always	☐N/A ☐1. Chats/texts (informal) ☐2. Emails ☐3. Phone calls ☐4. Meetings (in-person or virtual)	☐N/A ☐1. Slightly important ☐2. Important ☐3. Very important ☐4. Extremely Important ☐5. Critical
3.	☐N/A ☐1. Minimal ☐2. Sometimes ☐3. Frequently ☐4. Very frequently ☐5. Always	☐N/A ☐1. Chats/texts (informal) ☐2. Emails ☐3. Phone calls ☐4. Meetings (in-person or virtual)	☐N/A ☐1. Slightly important ☐2. Important ☐3. Very important ☐4. Extremely Important ☐5. Critical
4.	☐N/A ☐1. Minimal ☐2. Sometimes ☐3. Frequently ☐4. Very frequently ☐5. Always	☐N/A ☐1. Chats/texts (informal) ☐2. Emails ☐3. Phone calls ☐4. Meetings (in-person or virtual)	☐N/A ☐1. Slightly important ☐2. Important ☐3. Very important ☐4. Extremely Important ☐5. Critical
5.	☐N/A ☐1. Minimal ☐2. Sometimes ☐3. Frequently ☐4. Very frequently ☐5. Always	☐N/A ☐1. Chats/texts (informal) ☐2. Emails ☐3. Phone calls ☐4. Meetings (in-person or virtual)	☐N/A ☐1. Slightly important ☐2. Important ☐3. Very important ☐4. Extremely Important ☐5. Critical

Section 3: Design evaluation

The team collectively laid out some important aspects for this project; please give a score from 1-10

(1= very poor, 5=neutral, 10= excellent) to how well and satisfied are you - so far into the design - with the team's achievement and fulfillment of these requirements, goals, and constraints.

1	Academic programming requirements are supported
2	Food service (2 sections)
3	Bookable meeting spaces (2 sections)
4	Indigenous recognition (including artwork from below)
5	Lounge space (2 sections)
6	Acoustics and Daylight views (Right to Light)
7	Flexibility for future expansion
8	Durable material selection with low operational and maintenance requirements
9	Simple, effective & efficient technology selection for good performance
10	Indoor Safety (slip, fall)
11	Security (Video cameras, access system, etc.
12	Overall cost reduction and competitive prices
13	Barrier-free access and signage
14	Exhibit Space
15	Interactive AV/Digital wayfinding

Appendix B – Survey for Chapter 5

Part One: Background Information

1 Please specify the type of degrees or certifications you earned in the AEC domains. (Check all that apply)

☐Undergraduate
☐Master's Degree
☐PhD Degree
☐Educational Certification
☐More/Other (*please specify*): _____

2 Please specify information about your background degrees:

University Name _____
Years of Graduation (if currently enrolled, please write continuing):_____
Degree field_____

3 How long have you worked in the AEC industry?

☐Not applicable
☐Less than 6 months
☐6 months-1 year
☐1-3 years
☐3-5 years
☐Other (*specify in years*): _____

4 How many different firms in the AEC industry have you worked with? (Minimum of 6 months in each firm)

5 What category best describes your current job role? (Check all that apply)

☐Student (currently enrolled)
☐Professional engineer
☐Architect
☐Engineer educator or college/university professor
☐Architecture educator or college/university professor

☐Other (please specify): _____

Part Two: General overview of the A/E/C education

Please reflect on your formal education and rate your agreement with the following statements (1= strongly disagree, 2= disagree 3= slightly disagree, 4= neutral, 5= slightly agree, 6= agree, 7= strongly agree)

1. Formal education provides students with sufficient *knowledge* about the social, environmental, and economic requirements on construction projects.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
2. I have some concerns that formal education lacks the courses that teaches the impact of projects on human life and social needs (ex: psychological effects of the built environment, etc.).	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
3. Course/Academic ***projects*** that students engage in are a good representation of *real-life projects.*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
4. Formal education helps students acquire strong skills to enhance *creativity* and *innovative thinking processes.*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
5. Formal education provides students with sufficient *technological advancements* and tools to work **collaboratively** in the industry (ex: BIM, Revit, etc.).	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7

Part Three: Engagement with different disciplines and engaging owners/practitioners

Please identify the frequency of the following (1= never, 2= very rarely, 3= rarely, 4= occasionally, 5= frequently, 6= very frequently, 7= always)

1. During course work, I was engaged with teams from different disciplines on common projects.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
2. During my academic studies, I had courses/workshops that introduced me to the importance of collaborating with different engineering disciplines to achieve common goals on projects (could be courses, seminars or workshops, or common activities, etc.).	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
3. During my course work, I was taught about the importance and principles of integration on construction projects (ex: involving the contractor early on during design, involving the end-user, etc.).	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
4. During my engineering capstone projects (Final Year Project) or architectural projects, the panel or the jury members included not only faculty members but also owners/clients, practitioners from companies, etc. (assess based on the approximate % of projects that involved extended parties other than faculty).	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7

Part Four: Delivering value on construction projects.

Please evaluate each statement and your agreement with it (1= strongly disagree, 2= disagree 3= slightly disagree, 4= neutral, 5= slightly agree, 6= agree, 7= strongly agree)

1.	Before design starts, if the proper questions are asked by the designer, an owner will be able to express: what they value on projects, their needs and their requirements.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
2.	I believe some requirements are implicit, and it is the architects'/engineers' role to make them explicit and uncover these hidden needs during the building design process.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
3.	I believe that satisfaction of the owner is the primary objective of any project.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
4.	I believe the satisfaction of all major involved stakeholders is *NOT* a significant issue.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
5.	I think that architects formulate their own understanding of the project without engaging with different engineering disciplines.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
6.	I believe designers need to dig into the **reasons** behind the owners' requirements to provide more **design alternatives**.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
7.	I believe rework on projects is mainly due to the lack of sharing of information among different designers and engineers in due course (appropriate time) during the early design stages.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
8.	I believe conflicts are mainly due to the improper management of the contradicting goals of the people involved on projects.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
9.	I believe that during the **construction** phase, new requirements would be revealed with the engagement of more stakeholders and some other requirements would be changed.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7

Based on the above, we define project value as: the collective needs, requirements and desires of different stakeholders that are negotiated and agreed on during project development. Project value represents the guiding principles for achieving successful projects.

Based on the above description, have you heard of the **term** *identifying value* on projects?

☐Not heard of/not sure if I heard of
☐Heard of but have no explanation of it
☐Have general idea about it
☐Have basic knowledge
☐Have good knowledge

If you answered basic or good knowledge, please specify the means for acquiring this knowledge (ex: took a course, from a workshop, informally from work, etc.) _____

Based on the above, have you heard of ***methods*** *for improving the delivery of value* on projects?

☐Not heard of/not sure if I heard of
☐Heard of but have no explanation of
☐Have general idea about it
☐Have basic knowledge
☐Have good knowledge
If you answered basic or good knowledge, please specify the means _____

Part Five: Interest of students/practitioners in learning about the concept of value

Please rate the following as you think are important to be included in the AEC curriculum (1= not important at all, 2= not important, 3= neutral, 4=possibly important, 5= important, 6=very important, 7= absolutely essential)

There is a need to include sessions to engage students from different disciplines to discuss what is important for them on a project.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
There is a need to be involved in mock-up negotiations to understand trade-offs on construction projects.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
There is a need to learn about the concept of delivering value on projects.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7

Optional: Please share one important aspect you think is needed in academia to improve the engineering and architectural practice.

Submit

Appendix C – Practical improvements in collaboration projects

Project 1 (the IPD project):

We actively collaborated with the project manager and participated in team meetings. The outcome of our engagement with the project manager and the ongoing discussions focusing on value enhancement, resulted in the development of an internal Memorandum. This document was subsequently distributed to both the company's leadership, where the project manager works, and the IPD team. We present below excerpts from the memorandum, which highlight key insights derived from the research detailed in Chapter 2.

35 YEARS

Memorandum

We should look to assign an attribute to each value as it is as important to know what is valued, what the Owner is neutral to and what is disliked or undesired. These attributes could be:

- Obligatory (regulations, codes, standards)
- Essential (important features or requirements)
- Desired (good to have)
- Neutral (indifferent)
- Resistance (against, not desired)

Place all the post-it notes on a whiteboard or wall. Ask focus group members to re-arrange or group the post-it notes. If a post-it notes is unclear ask the person that prepared it to explain or provide more information so that it can be grouped or categorized with all the other post-it notes. Try to consolidate the different headers and groupings to as few as possible.

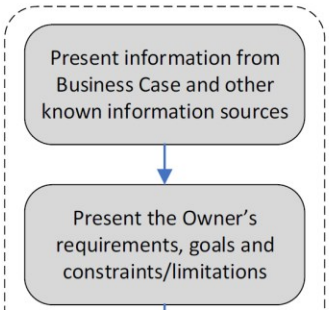
After the V_0 Session ISL or the IPD Advisor should carefully review all the data and information. Ensure that the grouping/headers are appropriate and then wordsmith the values into the Owner's requirements, goals and constraints/limitations. Make sure the language is clear and concise.

Send the Owner's requirements, goals and constraints/limitations to the Owner's Project Steering Committee for review. Obtain agreement or sign-off that it accurately reflects what the Owner knows at this stage of the project.

V_1 Session: Value Refinement

Shortly after the IPD Team has been onboarded and the Validation Phase commenced the IPD Team needs to grasp the Owner's requirements, goals and constraints/limitations and then given an opportunity to digest and contribute to the overall Project Objectives as a team.

At the start of the V_1 Session a knowledgeable individual from the Owner, or the consultant they retained to develop the business case present the project background information. ISL or the IPD Advisor could present this information if needed.



Once the focus group starts to lose steam it may be useful to ask more specific questions related to:

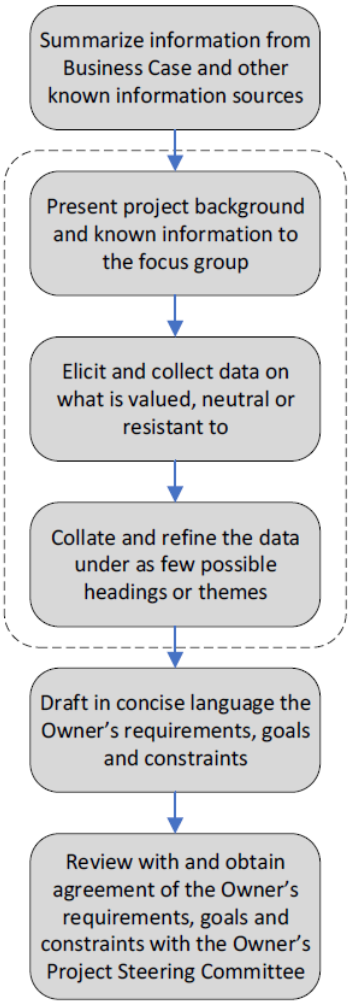
1. **Operational Values**
   a. How should or could the project or facility operate?
   b. Are there specific regulatory or authorities having jurisdiction (AHJ) requirements or limits that need to be met?
   c. Any specific safety requirements?
   d. Any specific operational or maintenance requirements or needs?

2. **Experiential Values**
   a. How do we want the staff or users to feel when experiencing or interacting with the project or facility?
   b. How do we want visitors to feel when experiencing or interacting with the project or facility?

3. **Triple Bottom Line (TBL) Values**
   a. Are there any social or aboriginal requirements or other needs?
   b. What are the environmental requirements?
   c. Are there any sustainability or other certification needs or requirements?
   d. Are there any economic or long-term financial requirements such as Return-on-Investment (ROI)?

4. **Financial Values**
   a. How much budget has been set aside for this project?
   b. Does the Owner feel this budget is realistic?
   c. Is there a contingency in the event the IPD Team cannot validate at the given budget?

5. **Behavioral Values**
   a. How would the Owner like the team to engage the Owner?
   b. How would the Owner like the team to interact globally?



Project 2: the educational building

I played a significant role in the project's value vision, contributing to two key aspects.

Firstly, I assisted in the creation of a comprehensive list of value attributes, which served as an integral component of the project's second phase, specifically the fit-out phase. This list guided the project team in the design and development of this project.

Secondly, I actively participated in the development of a monthly health check initiative for the project team. This health check was distributed and facilitated through the use of the Mento-meter platform, providing an ongoing means of assessing project team dynamics and performance. These contributions aimed to enhance project efficiency and overall team performance.

The project Core Principles remain unchanged and will carry through the project. The Core & Shell guiding principles are as follows:

1. Sustainability & Wellbeing
2. Integrating existing and future development
3. Community, Social, achievement and retention
4. Inclusive design principles
5. Adaptable, flexible and efficient spaces
6. Equity, Diversity and Inclusivity (EDI) and Indigenous Initiatives

The Core & Shell Value attributes include the following:
- Resources conservation (material, energy, water, etc.)
- Campus quality improvement & interface with the community
- Thermal comfort and environmental control
- Effective use of existing infrastructure
- Campus enhancement and improvement
- Site requirements and analysis (legal description, zoning guidelines, restrictions, policy)
- Adaptive re-use of historical elements and spaces
- Iconic design
- Aesthetically pleasing volumetric shape and form
- Landscape and surrounding integration with the building
- Building's coherence and dimensional composition
- Maintainability of the building

Rating

Please rate the Fit-out Value attributes as follows:
E = Essential (I believe it is important to have this Value attribute on this project)
D = Desired (I believe it is good to have it, if the budget allows it)
N = Neutral (I am neutral about having this value attribute on this project)
R = Resistant (I prefer not to include this value attribute on this project)

2. Equity, Diversity and Inclusion (EDI) *

The UofA standards will be met for All Gender Washrooms, Barrier-free access and signage as well as tactile wayfinding, however if you feel that any of the items should be designed above the standard, rate it either E or D.

Check all that apply.

	E	D	N	R
All Gender Washrooms	☐	☐	☐	☐
Barrier-free access and signage	☐	☐	☐	☐
Braille tactile wayfinding	☐	☐	☐	☐
Ergonomic and user friendly design (for individuals with disability challenges)	☐	☐	☐	☐
Service dogs' sanitary accommodation	☐	☐	☐	☐

3. Story Telling: history, future, present; Reflected in spaces *

Check all that apply.

	E	D	N	R
Indigenous recognition	☐	☐	☐	☐
Exhibit space: Museum presentations	☐	☐	☐	☐
Robotics labs (demonstrations in public spaces)	☐	☐	☐	☐
Students' project work	☐	☐	☐	☐