PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE

SCHOOL OF ENGINEERING

# ANALYSIS OF THE USE OF TARGET VALUE DESIGN IN THE GENERATION OF VALUE IN DESIGN

**ZULAY MERCEDES GIMÉNEZ DE BENAVIDES**

Thesis submitted to the Office of Graduate Studies in partial fulfillment of the requirements for the Degree of Doctor in Engineering Sciences

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Santiago de Chile, December, 2021

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Dedicated to my lovely husband, Luis José,
my sons, Luis, Jesús and David,
my parents, Leopoldo, Zulay and Pepe
and my entire family Giménez Palavicini and
Benavides Alvarado.
Thanks for your support and patience.

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**RESUMEN**

El proceso tradicional de diseño en la industria AEC (Arquitectura, Ingeniería y Construcción) no logra generar el valor esperado por el cliente. El diseño requiere el establecimiento de requerimientos del cliente, usualmente mal formulados y ambiguos, para generar un diseño completo y posteriormente evaluar aspectos de costo, tiempo, constructabilidad y otros criterios que, al ser considerados tardíamente, no necesariamente cumplen con los requerimientos del cliente, e históricamente han tenido resultados de ineficiencia y falta de calidad. Dentro de la industria AEC se han desarrollado prácticas de gestión que mejoran la productividad y generación de valor, tales como Target Value Design (TVD). Se cree que, al desplazar los esfuerzos de diseño hacia actividades preliminares, y considerando tempranamente objetivos de costos y valor del cliente, aplicando TVD, se generará mayor valor que en el diseño tradicional. El presente proyecto tiene como objetivo entender cómo TVD contribuye a generar valor en el diseño. Por ende, se desarrolla un modelo de análisis de valor a través de indicadores cuantitativos de valor en el diseño, para ser aplicado en: (1) proyectos bajo el esquema de proceso de diseño tradicional y (2) en proyectos bajo la intervención de TVD, con el fin de evaluar las diferencias y visualizar la influencia del TVD sobre el valor logrado en el diseño. Los principales resultados de esta investigación son, (1) un modelo de análisis de valor en la etapa de diseño, que ofrece mecanismos de medición de generación de valor e identificación de pérdidas de valor, (2) una mayor comprensión de pérdidas de valor durante el proceso de diseño tradicional y (3) evidencia del impacto sobre la generación de valor del uso de TVD en proyectos inmobiliarios.

Palabras Claves: Generación de valor, Industria AEC, Target Value Design, modelo de análisis del valor

**ABSTRACT**

The traditional design process in the AEC (Architecture, Engineering and Construction) industry fails to generate the value expected by the client. The design requires the establishment of client requirements, usually poorly formulated and ambiguous, to generate a complete design and subsequently evaluate aspects of cost, time, constructability and other criteria that, when considered late, do not necessarily meet the client's requirements, and historically have resulted in inefficiency and lack of quality. Within the AEC industry, management practices have been developed that improve productivity and value generation, such as Target Value Design (TVD). It is believed that by shifting design efforts to upstream activities, and considering early cost and customer value objectives, applying TVD will generate greater value than traditional design. The objective of this research is to understand how TVD contributes to generate value in design. Therefore, a value analysis model is developed through quantitative indicators of value in design, to be applied in: (1) projects under the traditional design process scheme and (2) in projects under TVD intervention, in order to evaluate the differences and visualize the influence of TVD on the value achieved in design. The main results of this research are: (1) a model of value analysis in the design stage, which offers mechanisms for measuring value generation and identification of value losses, (2) a better understanding of value losses during the traditional design process and (3) evidence of the impact on value generation of the use of TVD in real estate projects.

Keywords Value generation, AEC industry, Target Value Design, Value Analysis Model

# 1. INTRODUCTION

## 1.1 OBSERVED PROBLEM

The Architecture, Engineering, and Construction (AEC) industry recognizes the design process as a key to project success (or failure) (Knotten et al., 2016). Even though design costs are often less than 10% of the total construction cost or 1% of the project life cycle cost (Andi & Minato, 2003), decisions made in design have a significant influence on overall project performance (CURT, 2004). Errors, omissions, and deficiencies in the design stage bring consequences of rework, construction failures, cost and schedule variability, and decreased project productivity (Bustos, 2015; Knotten et al., 2015; Love et al., 2014; Thyssen et al., 2010). On the other hand, most design deficiencies are identified late during construction; however, there is a potential for some to remain undetected and contribute to project failure (Love et al., 2013).

For these reasons, several authors argue that the traditional design process in the AEC industry has been unable to meet customer value expectations (Gunby et al., 2013; Leinonen & Huovila, 2000). The design process must deliver value to customers within their satisfaction conditions, typically referring to cost, time, quality, and financial performance (Ballard, 2012a; Eskerod & Ang, 2017). However, there may also be other satisfaction conditions, such as sustainability, durability, operation, maintenance, social impact and safety (Ballard, 2020; Palaneeswaran et al., 2004; Tommelein & Ballard, 2016). These aspects are traditionally considered after the complete design has been generated and do not necessarily correspond to the customer requirements (Díaz, 2017). Satisfying customers implies understanding and resolving their different perspectives and rethinking their needs in constructive terms (Kamara et al., 2000b). If the value of clients is not fully understood in a construction project, the result is likely to be low compliance with client expectations or multiple design modifications during the project (Spiten et al., 2016).

Some authors suggest that by shifting the design effort to earlier stages and considering cost objectives and customer requirements beforehand, greater value will be generated (Ballard, 2020; CURT, 2004).

In recent years, the U.S. construction industry began using a management approach known as Target Value Design, an adaptation of Toyota's Target Costing to project delivery in the AEC industry (P2SL, 2020). After a failed attempt at implementation (Nicolini et al., 2000), it was first successfully applied in this industry in 2002 (Ballard & Reiser, 2004), and it is considered the explicit practice that represents Lean thinking in design (Novak, 2012). At first, it was applied in the AEC industry as "design to target cost," which belongs to the more general practice of designing to target characteristics, commonly referred to as DfX (Ballard & Reiser, 2004). Subsequently, the term Target Value Design, as it is known today, began to be used (Lichtig et al., 2005; Macomber et al., 2007)

TVD differs radically from the traditional way of designing. First, TVD is a method that makes customer constraints (cost, time, location, and others) the drivers of design in pursuit of value delivery (Ballard, 2020). Second, TVD defines a target cost based on a set price and profit margin (Rybkowski, 2009). Finally, TVD turns current design practice on its head because designers have to (1) design based on a detailed estimate; (2) design for what is buildable; (3) work together to define problems and produce decisions, and then design according to those decisions; (4) carry solution sets through to the design process; and (5) work in pairs or in a larger group face-to-face (Macomber et al., 2007).

While TVD is proposed to maximize value through design iteration within a pre-set cost target (Miron et al., 2015; Rybkowski, 2009), there is a knowledge gap around how much value is generated in TVD projects. As to date, it has not been possible to measure the value delivered to project customers in terms of requirements fulfillment and the evolution of customer-perceived value over time (Miron et al., 2015); just as early identification of value losses in any construction projects has not been possible (Bølviken et al., 2014; Love et al., 2013).

## 1.2 RESEARCH PURPOSE

It is clear that the AEC industry is trying to change the culture toward an emphasis on early-stage development through integrated and collaborative teams, concurrent and multilevel processes, focus on best value, and use of digital and virtual technology-based information and communications (AIA, 2007; Jia et al., 2017; Volkova & Jākobsone, 2016). The TVD approach enables a project environment with favorable characteristics for value generation, including an emphasis on design activities, making the customer an essential participant in the process (Ballard, 2011; Nanda et al., 2017). However, the main measurement performed in TVD is not focused on value, but on cost (Miron et al., 2015; Pennanen et al., 2010). In TVD there is a systematic cost reduction, identifying concrete actions, incentivizing, and continuously estimating the proposed changes to achieve the target cost. Likewise, it seeks to maintain the value requested by the client, controlling the scope or main objective of the project (Lee et al., 2012) or some measurable conditions such as metrics, capabilities, among others (Pennanen et al., 2010; Zimina et al., 2012). However, there is no evidence of measuring subjective satisfaction conditions or systematically reducing value losses to achieve the target value.

The purpose of this research is to understand how TVD contributes to the generation of value in design. For this purpose, a value analysis model is proposed and developed to analyze the value generation and losses in traditional design; and, subsequently, to evaluate the relationship of TVD with the value achieved during a design intervention.

## 1.3 RESEARCH QUESTIONS

This study addresses the following general research question: How does TVD contribute to the generation of value within the design? In order to address this conceptual research question, the following three operational questions are sought to be answered:

(1) How should value generation and losses in design be measured and analyzed?

(2) How is the process of value generation and losses in the traditional design process?

(3) What is the impact of TVD on the value generation of the design process?

## 1.4 RESEARCH GOALS

The main goal of this research is "to understand how TVD contributes to the generation of value in design." The specific objectives are as follows:

- Specific Objective 1: To propose and evaluate a method of analysis of value generation in design. This method should respond to the need to measure the value creation expected by the different customers within the design process through indicators and to contribute to the early identification of value losses to control them in time.
- Specific Objective 2: To understand the generation and losses of value in the traditional design process. This objective is achieved by exploring how the design building process responds to client needs under different

conditions of satisfaction and by identifying the most significant value losses.

- Specific Objective 3: To evaluate the impact of TVD on value generation in the design process. This objective is achieved by determining how the target value is fulfilled in the TVD project environment.

## 1.5 RESEARCH METHODS

To answer the research questions related to the contribution of TVD on the value generated in design projects, it was necessary to create a model that could (1) analyze and measure the value expected by clients, (2) measure the value generated in the design, and (3) identify value losses. For this reason, the first phase of the research was the development of a method named Value Analysis Model. Subsequently, the model was applied in two additional phases: phase 2, in traditional design projects, and phase 3 in TVD, in order to understand how value is generated in both design methodologies. Figure 1-1 presents an overview of the objectives and methodology for each phase.

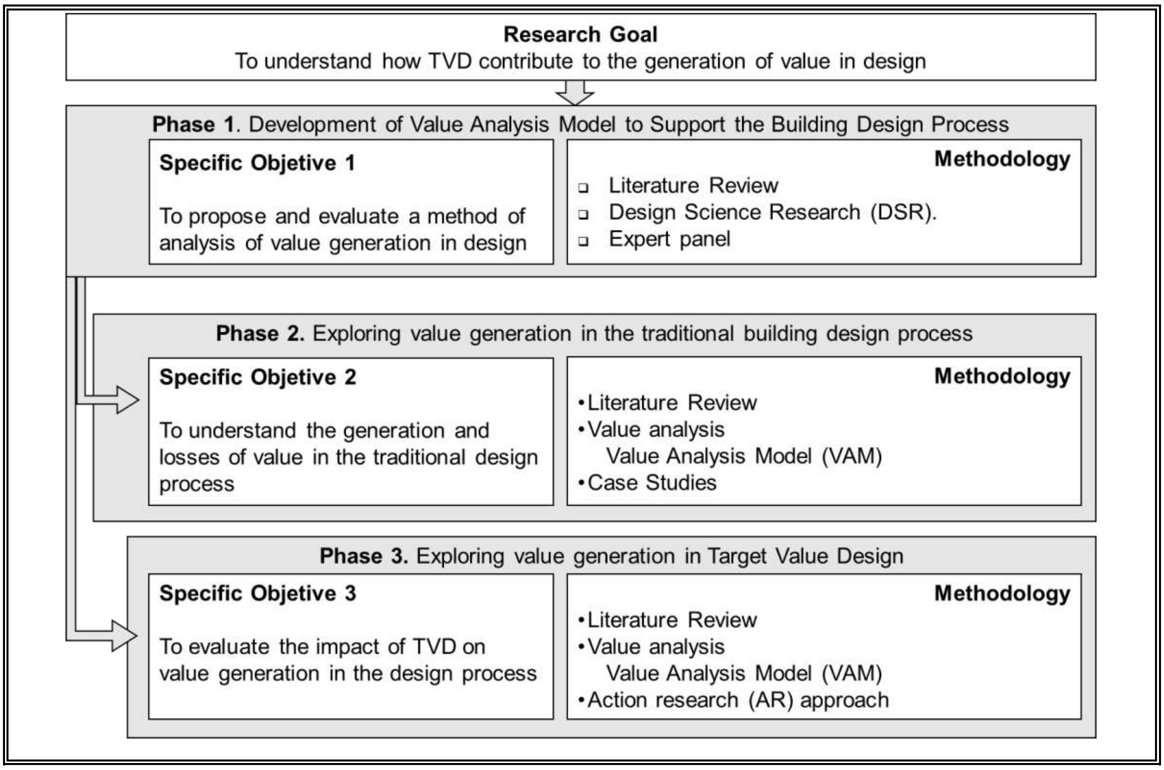



Figure 1-1. Overall research method

The model was developed under the Design Science Research methodology (DSR) and takes Kano's attractive quality theory as reference. The resulting VAM allowed measuring and analyzing the value through the indexes of desired, potential, and generated value, the identification of value losses and the percentages of value fulfillment related to the design stage. Validation of the model was performed through a panel of experts and the use of a pilot project with data from the design process and product under the perspectives of the owner, designers, and builders.

Phase 2 studies the generation and loss of value in the traditional design process to understand how it responds to customer needs based on different satisfaction conditions and identifies the most common value losses. The research methodology is based on the application of the value analysis model (VAM), in three traditional housing design projects as case studies to explore the desired, potential, and generated value for four clients: owners, designers, builders and end users.

Phase 3 explores the value generation and losses of a TVD project. The research methodology is based on the application of the action research (AR) approach to implement TVD within a pilot project in a housing development and construction company. Also, this phase illustrates the measurement and evolution of value, through the application of VAM, and compares them in terms very similar to those of the calculation and evolution of the target costing.

## 1.6 DISSERTATION OUTLINE

This dissertation comprises five chapters and follows a journal paper format, consisting of three papers. The three papers address the research questions 1, 2 and 3, and they correspond to chapters 2, 3 and 4 respectively. Each of these chapters contains its own introduction, research methodology, results, discussion of results, conclusions, and references. Figure 1-2 presents an overview of the objectives, and main results for each chapter.

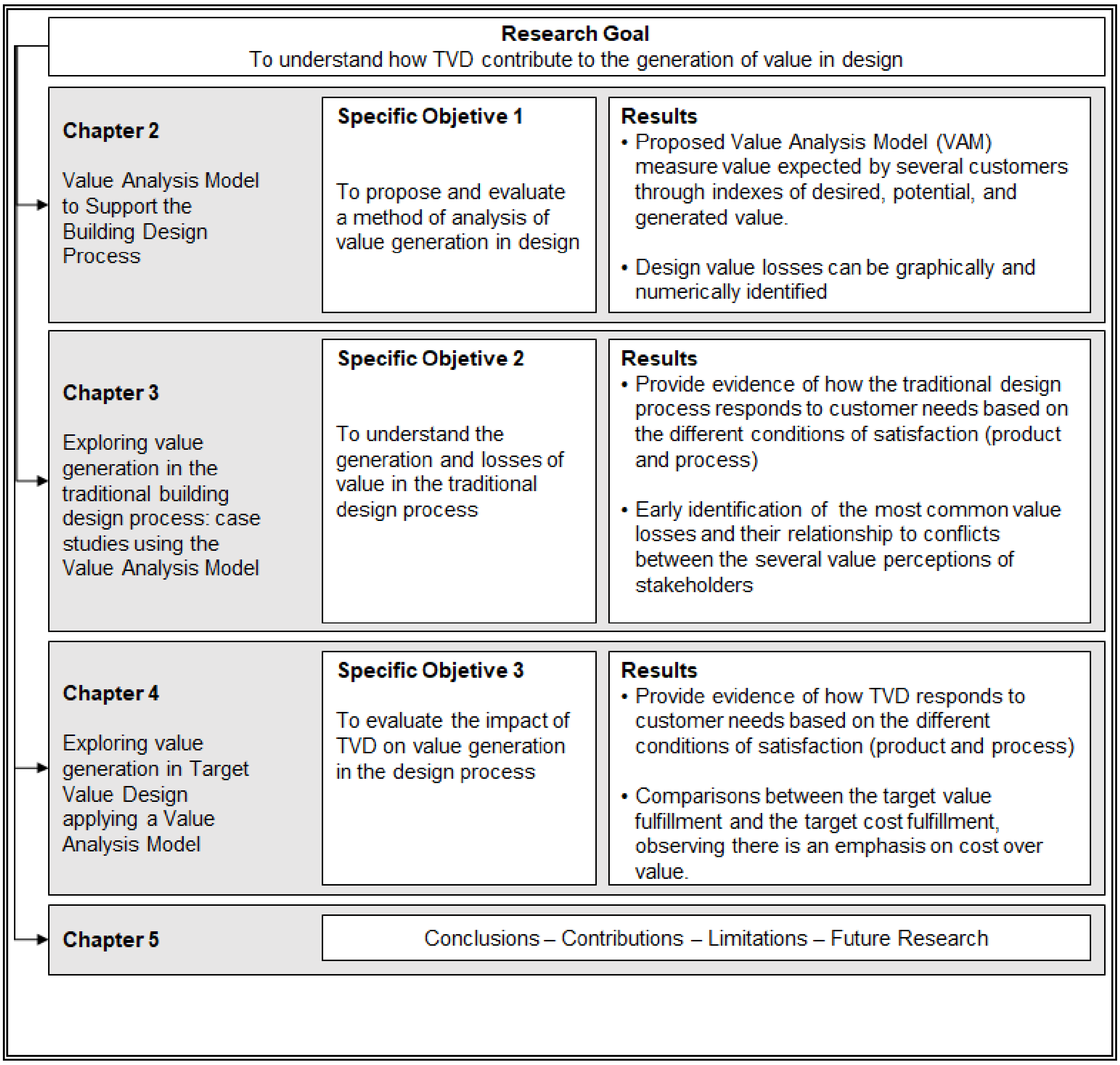



Figure 1-2. Overview dissertation outline

Chapter 2 presents the development of a value analysis model (VAM) to measure the value creation expected by customers and to identify value losses through indexes.

Chapter 3 studies the generation and loss of value in the traditional design process to understand how it responds to customer needs based on different satisfaction conditions and identifies the most common value losses.

Chapter 4 explores the value generation and losses of a TVD project.

Chapter 5 discusses the general conclusions, limitations, and contributions of this study. It also presents recommendations for different topics that could be considered for future research.

# 2. VALUE ANALYSIS MODEL TO SUPPORT THE BUILDING DESIGN PROCESS

## 2.1 INTRODUCTION

The design process in the architecture, engineering, and construction (AEC) industry is unable to respond to the value creation expectations of the customer (Gunby et al., 2013), nor does it use rigorous methods that measure value or identify and control value losses (Ballard, 2012a; Koskela, 2000). A design initially requires establishing customer requirements, which are usually incomplete, poorly formulated, and ambiguous (The Standish Group, 2014), to generate a complete design and then evaluate aspects of cost, time, quality, and other criteria. These aspects, when considered late, do not necessarily correspond to the clients' value requirements (Díaz et al., 2017), and historically have been exceeded or deviated from (Bustos, 2015; Love et al., 2014; Thyssen et al., 2010), producing consequences of inefficiency and lack of quality and productivity in projects (Knotten et al., 2015). Satisfying clients involves understanding and resolving their different perspectives and restating their needs in construction terms (Kamara et al., 2000b).

Design is an interactive and multidimensional effort that should represent the interests of several stakeholders and customers (Bonnier et al., 2015). However, the inability to study, understand and consider customer needs within the industry is widely recognized (Kumar & Whitney, 2007), as even customer interaction in the design process is perceived as a nuisance (Arge, 2008). Womack & Jones (2012) consider goods and services that do not respond to user needs as waste within design. If customer value is not fully understood in a project, the project is very likely to result in low compliance with customer expectations or multiple modifications during the project (Spiten et al., 2016).

To date, it is not possible to measure the value delivered to project customers, not only regarding costs or objective measurements but also concerning compliance with requirements and the evolution of the value perceived by customers over time (Miron et al., 2015). In addition, it is expected that some customer requirements may be lost during design (Fischer et al., 1991). Still, these value losses are generally not discovered in the process (Bølviken et al., 2014) or are identified late in the construction stage (Love et al., 2013).

Considering this gap in the body of knowledge, this research aims to respond to the need to measure the value creation expected by different customers within the design process through indicators and contribute to the early identification of value losses to control them in time. A value analysis model (VAM) is proposed to measure the value creation expected by customers and to identify value losses in the building project design process through indexes that take the Kano model (Kano et al., 1984) and target costing (Tanaka, 1993) as points of reference. VAM was developed under the design science research (DSR) methodology, which focuses on solving practical problems and producing artifacts as outputs (Holmström et al., 2009). One of the main contributions of the model proposed in this study is the possibility of better understanding the concept of the value and how to capture and measure it and knowing when and how value can be lost to support the conditions of customer satisfaction.

## 2.2 RESEARCH METHOD

### 2.2.1 Overall Approach

The VAM was developed on the conceptual basis of design science research (DSR). DSR is used to explore new solution alternatives to solve problems and to develop or create an artifact (Holmström et al., 2009). Such artifacts are potentially constructs, models, methods, or any designed object in which a research contribution is incorporated into the design (Peffers et al., 2007). DSR bridges the gaps among the contextual environment of the research project, design science activities, and the knowledge base of scientific foundations, experience, and expertise, iterating between the activities of construction and evaluation of research design artifacts and processes (Hevner, 2007). According to Thuan et al. (2019) every study has a research motivation that contextualizes a problem statement that in turn drives the research approach toward the use of theory and activities in research itself, all in order to generate the product or artifact.

Figure 2-1 presents the research approach based on the DSR process model proposed by (Peffers et al., 2007), which comprises five iterative steps: Problem identification and motivation; definition of the objectives; design and development; demonstration; and evaluation. In this case, the developed artifact is the VAM.

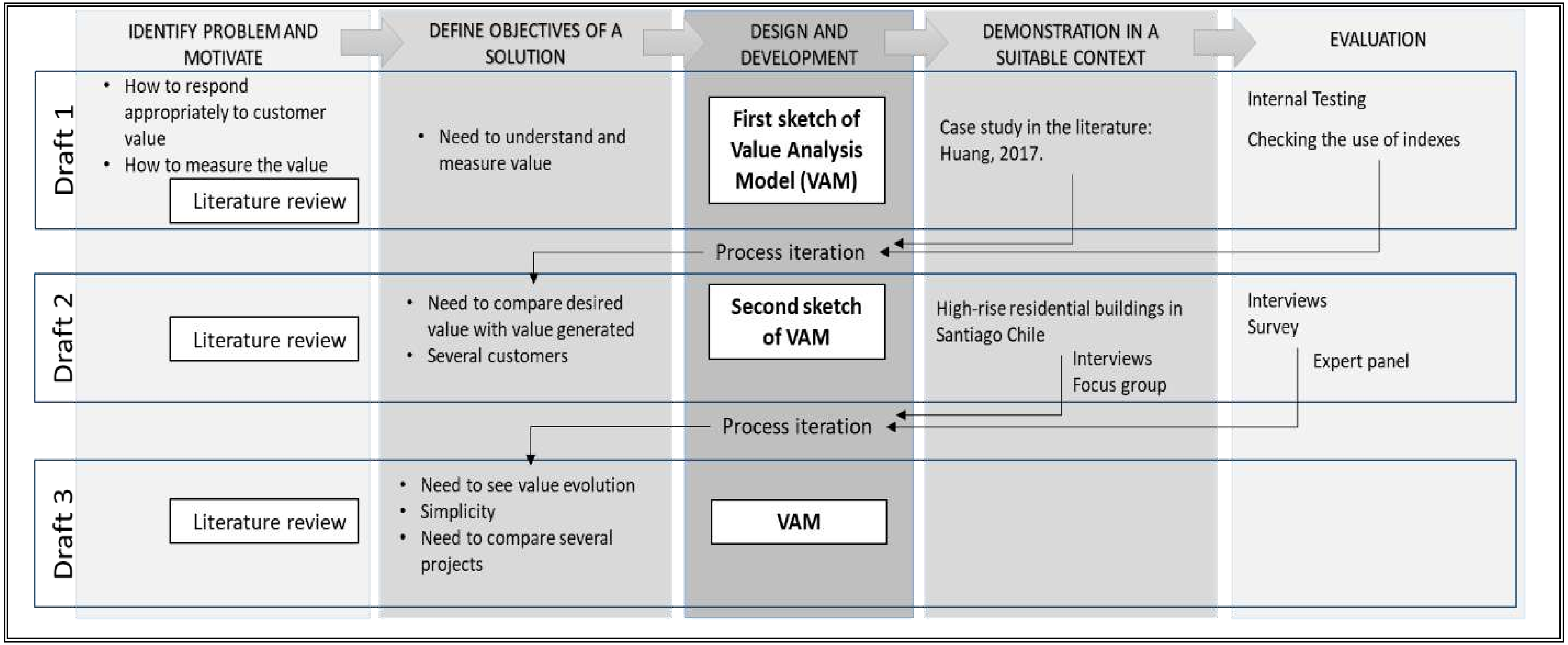



Figure 2-1. Research approach based on design science research (DSR).

Regarding problem identification, a literature review is performed on value and customer concepts, generation and loss of value, and value-related methods in the AEC industry. The VAM artifact was developed in two complete iterations using different case studies in each cycle to deliver three drafts. The first cycle used a project present in the literature as a case study: An application of the Kano model in requirements analysis of a company's consulting project located in Guangzhou (Huang, 2017). The second cycle utilized two projects of a Chilean real estate and construction company, whose primary activity is the integral execution of high-rise residential buildings. Each cycle included the five steps introduced previously: Identification, definition, design and development, demonstration, and evaluation.

The developed artifact was evaluated in terms of usefulness, practicality and ease of use, adaptability to the studied context, logic and congruence with theoretical aspects in each cycle or draft.

The following sub-sections explain in-depth each one of these activities within their corresponding iterations.

### 2.2.2 Problem Identification and Motivation: Literature Review

a) Value

Different value concepts with similar approaches have been presented in the literature. Value is generally expressed as a relationship between two aspects, such as function and the total life cycle cost of that function (Novak, 2012) or costs and benefits (Rachwan et al., 2016). Other authors express value as the relationship between the effectiveness of a product in achieving the objectives and the resources consumed, what you get and what you give, or the balance between the benefits and sacrifices involved in value judgments (AFNOR, 2000; Kelly et al., 2008; Saxon, 2005). All these definitions can be summarized as the relationship between the satisfaction of needs and the use of required resources.

In the context of Lean Management, value is defined from the customers' perspective, in relation to concerns to be addressed in order to obtain a desired product and achieve their objectives(Bølviken et al., 2014; Macomber et al., 2007; Rybkowski et al., 2012; Womack & Jones, 2012). Likewise, value is differentiated from cost or its reduction, quality or waste reduction(Salvatierra et al., 2012). It can also be seen as the evaluation made by an observer referring to a set of standards in which what is observed is better after the effort than it was before (Macomber & Howell, 2004).

Value can be seen in several ways by different customers in diverse situations. Value will be defined differently by each stakeholder depending on his or her judgment of the factors given and received, just as value depends on the theoretical context and on subjective perceptions and evaluative judgments (Drevland et al., 2018). That is, what is value for one may not have any value for others (Koskela, 2000). On the other hand, value may vary over time (Eskerod & Ang, 2017), as customers' needs are dynamic (Bolar et al., 2017) and the context may change; therefore, value judgments made at different times will differ (Drevland et al., 2018). The value generated through the projects and activities is not static but flows (ripple effect) to generate value in other areas in the present and in the future to benefit different stakeholders. (Eskerod & Ang, 2017). In this value dynamism, one can distinguish the pre-use value, also called the expected or desired value, and the post-use value, also called received or perceived value (Gallarza et al., 2016; Kowaltowski & Granja, 2011; Tucker et al., 2012). In the context of this research, value is defined as the fulfillment of the needs of different customers considering their diverse visions, the dynamism of value over time, and the resources contributing to value generation.

b) Customer

An essential consideration for value management is the impact of the customer on the project process (Kelly et al., 2008). In business terminology, the words "customer" (product buyer) and "consumer" (end-user of the product) are often used interchangeably (Bolar et al., 2017). However, the customer may be different from the end-user (Lee & Paredis, 2014). In quality management, the customer concept is broadened by considering external customers (any person who is not part of a company and purchases its products and/or services) and internal customers (any person who is part of a company and who receives a product—information, materials, or parts—to which he or she adds his or her own work and delivers it to another customer) (Camisón et al., 2006). According to Kamara et al. (2000a), the client should represent the interests of users and other identified persons, groups, or organizations who influence and/or are affected by the acquisition, use, operation, and demolition of the facility being commissioned. In a similar sense, Drevland & Tillmann (2018) relate the customer to all the people who are somehow affected by a project (stakeholders), and these authors classify the customer and stakeholders within a single group because of the relationship between them. In the context of this research, the term “customer” will be used interchangeably with “client” and “stakeholder.”

c) Generation and Loss of Value

The process of generating value has been discussed from many points of view. Leinonen & Huovila (2000) define this process in three phases: (1) Determining the customer's requirements, (2) creating solutions to meet these requirements, and (3) verifying during the project that these requirements are met in the best way possible. Customer requirements refer to the objectives, needs, wishes, and expectations of the customer. These requirements should be a description of the functions, attributes, or other special features of the facility necessary to satisfy the needs of the customer (Kamara et al., 2000a). Zhang et al. (2016) relate value generation to maximizing value, minimizing the life cycle cost, and considering customer needs. Value maximization can be achieved by balancing the number of needs met with the resources used. Koskela (2000), on the other hand, defines five principles of value generation within the production process, relating them to the internal functions of the supplier and the customer:

i) Requirements capture: Ensuring that all customer requirements, both explicit and implicit, have been captured as the first step in generating value.

ii) Requirements flow-down: Ensuring that all relevant customer requirements are retained in all phases of production and are not lost when progressively transformed into design solutions, production plans, and products.

iii) Comprehensive requirements: Ensuring that all requirements relate to all customer roles.

iv) Production subsystem capacity: Ensuring the capacity of the production system to produce products as needed.

v) Value measurement: Through metrics, ensuring that value is generated for the customer.

Additionally, Koskela (2000) incorporates the term loss of value to refer to the part of value that is not provided, even if providing it is potentially possible. This concept is a way of measuring value in relative terms, that is, the value achieved compared with the best possible value. For their part, Womack & Jones (2012) suggest considering the provision of an incorrect product or service as waste.

In Lean philosophy it is common to relate value to waste (Arroyo & Gonzalez, 2016; Gomes & Tzortzopoulos, 2020; Salvatierra et al., 2010), the main objective of lean construction is to eliminate waste from the system by trimming production so that it delivers as much value as possible (Emuze & Saurin, 2016). From the perspective of value of TFV Theory(Koskela et al., 2007), waste is the loss of value, defined by a situation in which a product is not used correctly, there is a loss of quality, tasks are not performed in the way they should be, or byproducts with harmful or undesirable value are obtained (Bølviken et al., 2014). The main principle of value generation is to eliminate value losses, which according to Tillmann & Miron (2020) have been realized through rigorous analysis of customer requirements, systematic management of their flow, working within the limits of economically viable solutions, project integration and extensive value management considerations for the pursuit of optimization.

Respect to "potentially possible", one way of determining it is to look at competitors; if they provide more value, providing more value is also potentially possible for the company in question. Another way is to estimate the value when the whole cycle of product realization is ideal (Koskela, 2000).

Integrating these perspectives, the following elements are summarized below as influential factors within the value generation process:

i) Minimization of the life cycle cost.

ii) Pursuit of the satisfaction of customers' needs.

iii) Pursuit of value maximization.

iv) Requirements capture.

v) Requirements flow-down.

vi) Pursuit of integrated solutions for the fulfillment of requirements.

vii) Assurance of the capacity and performance of the production system.

viii) Verification that the requirements are met.

ix) Value measurement through metrics.

x) Identification of value losses.

d) Value-Related Methods in the Architecture, Engineering, and Construction (AEC) Industry

Value management, also known as value analysis (VA), value methodology, or value engineering (Rachwan et al., 2016), is a management style that has evolved from previous methods based on the concept of value and the functional approach. These methodologies were first proposed in the 1940s and 1905s by Lawrence D. Miles, who developed the VA technique as a method for improving the value of existing products (Novak, 2012). Initially, VA was used to identify and eliminate unnecessary costs. However, it is equally effective in increasing performance and addressing non-cost resources (AFNOR, 2000).

In general, value is understood in terms of cost, price, or monetary aspects (Saxon, 2005). However, others focus on customer voice and preferences, such as stated preferences (Kowaltowski & Granja, 2011), evidence-based design (Rybkowski et al., 2012), the design performance measurement matrix (Yin et al., 2011), design thinking (Volkova & Jākobsone, 2016), the design value scorecard (Westcott et al., 2014), agile transform development (Heikkilä et al., 2017), the value chain model (Porter, 1985), the balanced scorecard (Kelly et al., 2008), the maximum difference method or Best-Worst approach (Farías & Fistrovic, 2016), the voice of the customer (VOC) (Franco & Picchi, 2016), and the framework for value-optimized design (Amini et al., 2016).

Within the context of the AEC industry, methods such as post-occupancy evaluation (POE) (Menezes et al., 2012), virtual design and construction (VDC) (Zhang et al., 2018), and target value design (TVD) (Zimina et al., 2012) have been created and used. Value-related methods used in other industries have also been incorporated into the AEC industry, such as stated preferences, design thinking, value engineering (Rachwan et al., 2016), quality function deployment (QFD) (Bolar et al., 2017), the Kano model (Borgianni, 2018), and target costing (Kron & von der Haar, 2016). Furthermore, additional methods have been developed for some "ad hoc" needs within the AEC industry (García & Solís, 2008; Gunby et al., 2013; Haddadi et al., 2016; Pandolfo et al., 2008).

Table 2-1 summarizes information on the methods used in the AEC industry and their relationship with the influential factors within the value generation process. The factors established in 2.2.2 were considered, including the relationship with other factors such as quality, constructability, and productivity; although they may be part of a customer's requirements, they are often confused with the definition of value (Salvatierra et al., 2012).

In one way or another, all methods aim to satisfy customer requirements. However, to comply with them, methods do not necessarily focus on their capture, flow, and subsequent verification of compliance; rather, they focus on aspects of quality, constructability, and productivity. The limited use of strategies to capture requirements or to identify value losses during the design process, the nonconsideration of the assurance of the production system's capacity, and the generalized lack of the use of metrics or indexes related to value are also visualized.

Table 2-1. Methods and their relationship with value generation

| **Methods** | **Influential Factors Within the Value Generation Process** | | | | | | | | | | | **Reference** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Minimization of the life cycle cost | Pursuit of satisfaction of the customer's needs | Pursuit of value maximization | Requirements capture | Requirements flow-down | Pursuit of integral solutions for the fulfillment of requirements | Assurance of the capacity and performance of the production system. | Verification that the requirements are met | Value measurement through metrics | Identification of value losses | Relationship with quality, constructability, productivity | |
| Post-occupancy evaluation (POE) | | x | | | | | | x | | x | x | (Kelly et al., 2008; Menezes et al., 2012) |
| Value Management/ Engineering | x | x | | | | | | | | | x | (Lin & Shen, 2007; Rachwan et al., 2016) |
| Kano Model | | x | | x | | | | | | | x | (Berger et al., 1993; Huang, 2017; Witell et al., 2013) |
| Quality Function Deployment (QFD) | | x | | x | x | x | | x | | | x | (Arroyave et al., 2007; Bolar et al., 2017; Díaz, 2017) |
| Target Costing | x | x | x | | | | | x | | | x | (Ballard & Rybkowski, 2009; Kron & von der Haar, 2016) |
| Virtual Design and Construction (VDC) | x | x | x | | x | x | x | | | x | x | (Díaz et al., 2017; Rischmoller et al., 2006; Song et al., 2017; Tauriainen et al., 2016) |
| Target Value Design (TVD) | x | x | x | | x | x | | x | | | x | (Rybkowski et al., 2012; Zimina et al., 2012) |
| Assessment of Housing Projects | x | x | x | | | | | | x | | x | (Pandolfo et al., 2008) |
| 3Cv + 2 | | x | x | | | | | x | x | | x | (García & Solís, 2008) |
| Framework for Enhancing Value Creation in Construction Projects | | x | | | x | | | | | | | (Haddadi et al., 2016) |
| Owner Value Interest Model | | x | x | x | | | | | | | x | (Gunby et al., 2013) |
| Stated Preferences | | x | | x | | | | | x | | | (Kowaltowski & Granja, 2011) |
| Design Thinking | | x | | | x | x | | x | | | x | (Volkova & Jākobsone, 2016) |

Regarding requirements capture, only four models have this emphasis: Kano, QFD, owner value interest, and stated preferences. QFD considers the capture of requirements only as a list of customer wishes, without considering any order of importance (Arroyave et al., 2007). The owner value interest model and the stated preferences model evaluate the degree of importance of each attribute or characteristic of value (Gunby et al., 2013; Kowaltowski & Granja, 2011). The Kano model measures customer feelings and the impact of product/service quality on customers' perceived satisfaction, classifying attributes according to their influence on customer satisfaction (Huang, 2017).

Concerning the identification of value losses, POE and VDC are discussed. POE is an evaluation of an inhabited property after use by a user; thus, value losses are identified too late to be corrected in time. Regarding VDC, its main contribution is the possibility of building virtually as the design is developed, thus achieving in a timely manner the identification of inconsistencies between design disciplines, aspects of quality and constructability, value loss in the design process itself, and the designed product. VDC is the use of integrated multidisciplinary performance models of design and construction projects to support business objectives, and it is used to emphasize product, organizational, and processual aspects (Kunz & Fischer, 2012). It is a value-related method in the AEC industry that considers ensuring the capacity of the production system.

Regarding the use of metrics or indexes related to value, Pandolfo et al. (2008) establish metrics of the importance perceived by customers of specific attributes with regard to their percentage within the cost to balance the use of resources with the "value" of the attribute. García & Solís (2008) focus on quality in the construction phase and beyond. Stated preferences evaluate the degree of importance of each attribute or characteristic and then determine a specific variable, called the general significance index (GSI).

None of the methods have all the factors considered influential or present in the generation of value. For this reason, the AEC industry has used them together to balance those that are missing. Among the methods that have comprehensive approaches to the most significant number of factors, VDC and TVD stand out. However, these two methods are notorious because they do not capture requirements in a systematic way or measure value through metrics or indexes.

e) Point of Departure

This literature review highlights a gap in current practices regarding the value generation of the design process within the AEC industry: There is a lack of adequate methods that link the suitable capture of customer requirements with the continuous measurement of the value generated as well as the timely identification of value losses at the time of design and not later, when it is no longer feasible to deal with them. There is a lack of indexes that allow value to be measured in an integral way considering the different perspectives of customers. The proposed value analysis model (VAM) can help designers and project managers improve decision making within the design process, increase customer satisfaction, and evaluate the allocation of resources to activities that generate value.

### 2.2.3 Draft 1

The first draft of the VAM addresses the need to understand and measure value in the design process. As points of reference, VAM takes the attractive quality theory of Kano et al. (1984), also known as the Kano model, as well as the coefficient of satisfaction (CS) of Berger et al. (1993). The Kano attribute classification allows requirements to be assessed according to the perception of the customer to calculate the desired value and the potential value of the process, by-products, and products of the design.

Kano et al. (1984) fundamentally distinguish the following types of attributes (Borgianni, 2018; Matzler et al., 1996): (1) Must-be attributes (M), which are essential elements of a product that contribute only to avoiding dissatisfaction; (2) one-dimensional attributes (O), in which customer satisfaction is proportional to the level of compliance with these attributes; (3) attractive attributes (A), which are attributes that have a significant influence on customer satisfaction because they meet the tacit needs and not just the explicit needs of the customer; (4) indifferent attributes (I), which are attributes that do not play a role in determining customer satisfaction; and (5) reverse attributes (R), which are product characteristics that are not only undesirable but also the opposite of what is expected.

Additionally, Kano et al. (1984) incorporate a requirements capture instrument that overcomes the bias that arises from traditional requirement survey instruments. Their instrument uses a two-dimensional questionnaire for each attribute to classify them. The first question is functional or positive (how do customers feel if the proposed characteristic is provided?); and the second question is dysfunctional or negative (how do customers feel if the intended characteristic is not provided?)(Huang, 2017).

Kano classifies each requirement according to most of the answers, which would not be statistically correct because, in general, the answers tend to be dispersed in several categories. For this reason, Berger et al. (1993) incorporate the CS, which is composed of two indexes (satisfaction—SI and dissatisfaction—DI) that represent, respectively, a positive number or the relative value of compliance with this customer requirement and a negative number or the relative cost of not meeting this customer requirement (see Equations 1 and 2). The CS positions each of the attributes in four possible quadrants: A, I, M, and O, thus contributing to the appropriate classification of the attributes according to Kano, as will be shown in Figure 2-3 and Table 2-4 much below.

$$SI = (O + A) / (M + O + A + I) \tag{1}$$

$$DI = (M + O) / (M + O + A + I) \tag{2}$$

In this first draft, it creates desired value and potential value indexes that represent the minimum and maximum value, respectively, needed to achieve the customer's requirements. A case study from the literature (Huang, 2017) was used to test the first draft of the VAM, which applies the Kano model to analyze the requirements of a project consulting firm based in Guangzhou whose main activity is the design and construction of roads. Huang (2017) establishes 18 attributes and classifies them using the Kano model, administering the two-dimensional questionnaire to 41 professionals among the company's managers and staff.

The results of this case study were applied to test the calculation of the value indexes and the relationships between them, the inclusion of the reverse attributes within the satisfaction coefficient, as well as different hypothetical scenarios of value generation and loss. After the use of VAM in this case study, the desired and potential value must be compared with the value generated, in addition to measuring value for the different customers present in the design process, such as owner, users, designers, and builders.

### 2.2.4 Draft 2

In Draft 2 of the model, the value indexes were generated, and the compliance and loss of value percentages were included to address the needs arising after testing the first draft. In addition, the second draft of the model identifies the relationship between the types of attributes and the generation or not of value.

The model was tested in two projects in the preliminary stages of the design process involving a real estate and construction company located in Santiago, Chile, whose main activity is the integral execution of high-rise residential buildings. VAM was applied in focus group meetings consisting of a cluster of 20 professionals that included directors and professionals from the company, such as architects, civil engineers, industrial engineers, and architectural engineers.

Initially, the focus group identified six main groups of customers. Later, it established for each type of customer a percentage according to the level of importance of each one. The different percentages were used as a weighting factor (W): Users (30.8%), owners (20.8%), designers (14.3%), builders (15.8%), reviewers (7.5%), and suppliers (10.8%). However, the state of progress (preliminary design) of both projects did not allow the incorporation of users, reviewers, and suppliers. For this reason, in this case, the VAM was applied only to designers, builders, and owners. The weighting factors were again established as follows: Owners (42%), designers (28%), and builders (31%).

In order to create the lists of attributes, interviews were conducted with the professionals about the positive attributes to be accepted and the negative ones to be avoided in both the design process and the product. Two types of products were established: A physical design product or deliverables and a conceptual or potentially buildable product after the design process. The final value attributes were identified and refined through an iterative review and revision process.

Subsequently, two-dimensional questionnaires were administered to owners, designers, and builders, such as surveys, to collect the first results regarding the desired value and the potential value of the process and the design products. Finally, the value generated in both projects thus far was measured.

Additionally, an expert panel was conducted through individual interviews in which the characteristics of the VAM and its operation were presented. This validation was achieved through an academic-industrial specialist panel, as shown in Table 2-2. Consistency, connection, coherency, simplicity, completeness, theoretically-based association, exactness, clarity, and use logic were checked.

In addition, the functional structure of the VAM was presented by Giménez et al. (2019) at an international event with experts in value generation and lean management issues. After this interaction with experts (panel and congress), the need emerged to compare the evolution value over time and increase the simplicity in showing and applying the model.

Table 2-2. Expert panel

| Profession | Occupation | Experience |
|---|---|---|
| Ph.D. Civil Engineer | Senior professor at a public university in Venezuela | 33 years of experience in construction management and quality |
| Ph.D. Civil Engineer | Senior professor at a public university in Spain | 28 years of experience in construction management |
| Ph.D. Civil Engineer | Project Manager. Bogotá, Colombia | 10 years of experience in construction |
| Ph.D. Civil Engineer | Corporate quality leader. USA | 13 years of experience in lean design and construction |
| MSc. Architect | Leader in Lean design and Integrated Project Delivery (IPD). USA | 25 years of experience in lean design |
| Ph.D. Civil Engineer | Associate professor at a public university in Brazil | 30 years of experience in construction management and economics |
| Civil Engineer | Talent development manager/LCI instructor. Perú | 14 years of experience in lean design and construction |
| MSc. Civil Engineer | Lean consultant. USA | 34 years of experience in design and construction |

### 2.2.5 Draft 3

For version 3 of the VAM, the possibility of several revisions of the value generated throughout the design project was incorporated, and the format of the questionnaires was simplified to meet the needs that emerged after evaluating the second draft. In response to the literature review, experiences related to the target cost (Tanaka, 1993) were included. Target costing is a disciplined process of determining the total cost of making a proposed product with specific functionality to generate the desired profitability at its selling price (Ballard & Rybkowski, 2009). In target costing, product design costs increase continuously until the allowable cost and the target cost (Rybkowski et al., 2012), which represent the willingness to pay and the customer's requirements and competitive conditions, respectively (Kron & von der Haar, 2016), are reached.

Like target costing, which iterates the design to achieve the allowable cost and target cost, the VAM has as its highest goal to accomplish in the design iterations the potential value, but if the desired value is achieved, the project is “valuably” feasible. In addition, the ease with which the model can be applied in different contexts has been improved. This paper introduces the latest version of this VAM.

## 2.3 RESULTS

### 2.3.1 Value Analysis Model (VAM)—General Overview

Next, a general overview of the VAM corresponding to Draft 3 of the model is presented. Each customer has requirements that represent design inputs. The preliminary stage of the design includes requirements capture, in which the customer's expectations regarding the product and the design process are captured, represented by the desired value (DV) and the potential value (PV). As a result of this first stage, the desired value and potential value indexes (DVI; PVI) of the process, the product, or both are obtained. Next, the design process begins; in this stage, the value that should respond to the desired value and could respond to the potential value is generated. As a result of this second stage, the generated value indexes (GVI) are obtained, which differ in the desired value generated (DVG) and potential value generated (PVG) of the process, the product, or both. Finally, deltas (or deviations) are obtained between the DVI and the DVG and between the PVI and the PVG. These comparisons give the measurement of value compliance, as well as the value losses present in the design. Figure 2-2 summarizes the model.

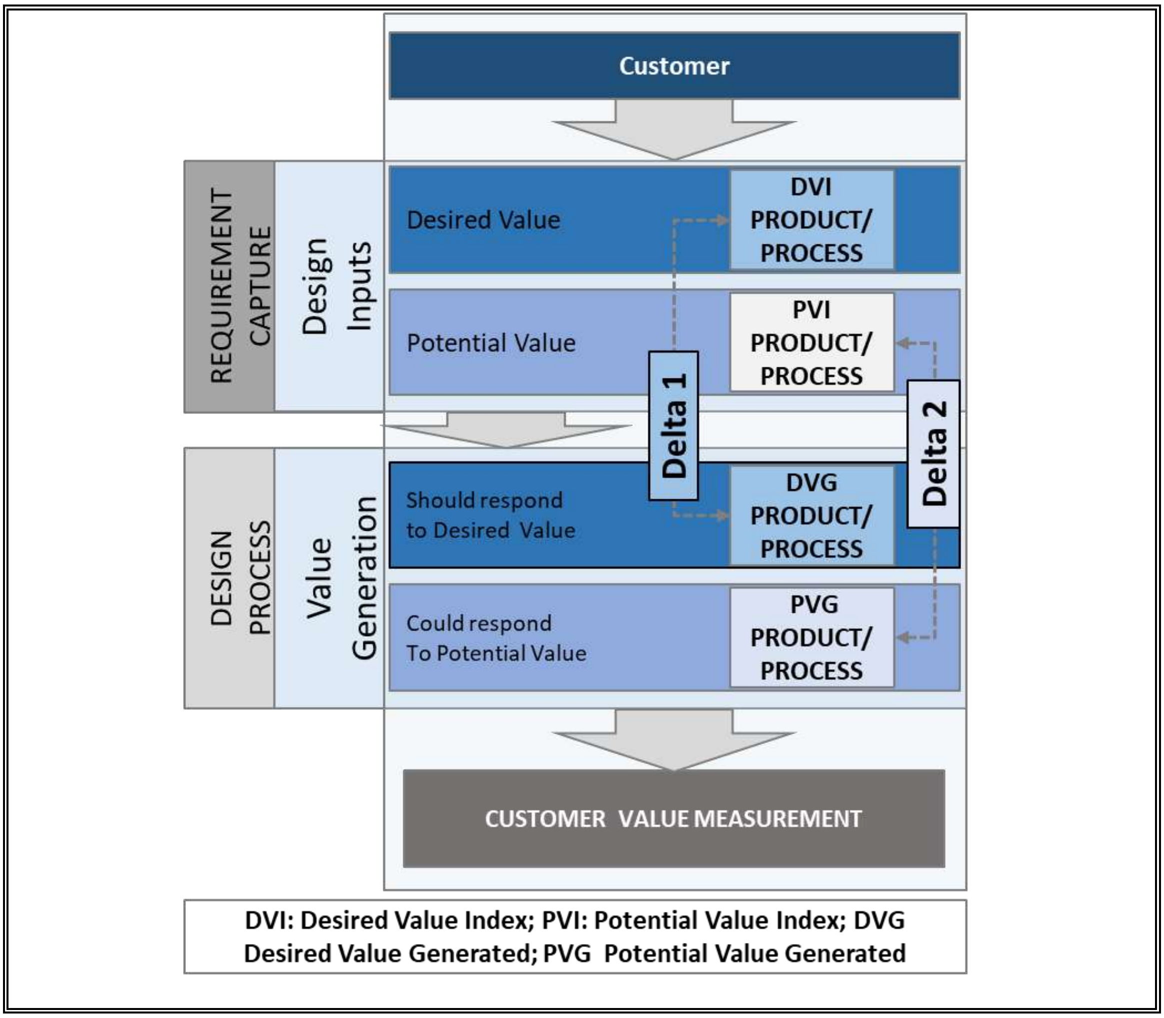



Figure 2-2. Value analysis model (VAM).

### 2.3.2 Requirements Capture—Design Inputs

a) Customer Identification

When starting to use the model, one customer must be identified, since value measurement must be done separately by customer or by customer groups by type: Designers, builders, owners, end-users, community members, etc. If it is necessary to review the value of different customers, the value measurement process must be repeated for each customer type.

b) Attribute List Creation

This list represents the standards to be evaluated by the customer. To make this list, the Delphi approach is recommended, in addition to the use of a literature review, a review of regulations and standards, and previous experience. It is essential to consider the needs and requirements of the customer in the different ways in which they are incorporated without obtaining detailed specifications. Attributes should be clear, brief, and precise, and should avoid confusing or ambiguous terms. They should be formulated with a simple, direct, and familiar vocabulary for the participants, refer to only one aspect or logical relation, and be written positively (Hernández et al., 2014). If a list of attributes has already been created with another similar group, it can be validated with the new group or it can be started from the beginning, depending on the evaluation group's assessment of the value. The person answering the questions should understand that the default answers will reflect a classification, not a ranking. For this reason, the answers should not be misinterpreted as a rating on a scale of 1 to 5, so they should not be numbered (Berger et al., 1993).

c) Attribute Classification

The classification proposed by Kano et al. (1984) is used. With the list of attributes, a two-dimensional questionnaire is prepared to assess each attribute. The first question is functional: How do customers feel if the proposed characteristic is provided? The second question is dysfunctional: How do customers feel if the intended characteristic is not provided? Each of the questions (whether functional or dysfunctional) has five response options: Like, must-be, neutral, live-with, and dislike. In this way, the attributes are classified by the customers themselves, to whom the questionnaire is administered. The attributes are then classified as M, O, R, A, and I attributes based on the matrix shown in Table 2-3. Q means that the question has probably been asked incorrectly or misinterpreted by the respondent.

Table 2-3. Kano's evaluation matrix.

| **Functional** | **Dysfunctional** | | | | |
|---|---|---|---|---|---|
| | Like | Must-be | Neutral | Live-with | Dislike |
| Like | Q | A | A | A | O |
| Must-be | R | I | I | I | M |
| Neutral | R | I | I | I | M |
| Live-with | R | I | I | I | M |
| Dislike | R | R | R | R | Q |

M = must-be, O = one-dimensional, R = reverse, A = attractive, I = indifferent, and Q = questionable.

Attribute classification generates a table with the list of attributes and the sums of the respondents' ratings. As an illustration, a fictitious example with 10 attributes is shown (see Table 2-4). Kano classifies each requirement according to most of the answers, which would not be statistically correct because, in general, the answers tend to be dispersed in several categories. In some cases, the first and second answers (even the third answer) are very close, and it is feasible to ask what the correct classification should be (see R3, R5, R7, and R9 in Table 2-4). For this reason, the CS proposed by (Berger et al., 1993) will be used.

Table 2-4. Example of a classification table.

| | | | | | | | | % 1st | Class | Berger original | | | Modified CS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Req | M | O | R | A | I | Q | Total | resp. | Kano | SI | DI | CS | SI-R | DI-R | CS-R |
| R1 | 7 | 9 | 1 | 19 | 5 | 0 | 41 | 46% | A | 0.70 | 0.40 | A | 0.66 | 0.41 | A |
| R2 | 24 | 11 | 0 | 4 | 1 | 1 | 41 | 59% | M | 0.38 | 0.88 | M | 0.38 | 0.88 | M |
| R3 | 17 | 20 | 0 | 2 | 2 | 0 | 41 | 49% | O-M? | 0.54 | 0.90 | O | 0.54 | 0.90 | O |
| R4 | 3 | 8 | 2 | 6 | 21 | 1 | 41 | 51% | I | 0.37 | 0.29 | I | 0.30 | 0.33 | I |
| R5 | 19 | 17 | 0 | 4 | 1 | 0 | 41 | 46% | M-O? | 0.51 | 0.88 | O | 0.51 | 0.88 | O |
| R6 | 27 | 3 | 1 | 5 | 4 | 1 | 41 | 66% | M | 0.21 | 0.77 | M | 0.18 | 0.78 | M |
| R7 | 13 | 9 | 0 | 14 | 3 | 2 | 41 | 34% | A-M? | 0.59 | 0.56 | O | 0.59 | 0.56 | O |
| R8 | 29 | 4 | 0 | 7 | 1 | 0 | 41 | 71% | M | 0.27 | 0.80 | M | 0.27 | 0.80 | M |
| R9 | 0 | 0 | 19 | 0 | 22 | 0 | 41 | 54% | R-I? | 0.00 | 0.00 | I | -0.46 | 0.46 | I |
| R10 | 0 | 0 | 31 | 0 | 10 | 0 | 41 | 76% | R | 0.00 | 0.00 | I | -0.76 | 0.76 | R |

Originally, in CS the R attributes were consciously ignored; the reason is not relevant and is beyond the scope of this paper. However, in this research, R attributes are included because it is important to determine which attributes a customer does not want to be present in the process or product. Considering that I attributes are neutral for the customer and that the inclusion of R is not desirable, it is preferable to classify an attribute as R instead of assuming that it is I (see R10 in Table 2-4). The R attributes will be included within the CS in the following manner:

$$SI = (O - R + A) / (M + O + R + A + I) \quad (3)$$

$$DI = (M + O + R) / (M + O + R + A + I) \quad (4)$$

M: Must-be, O: One-dimensional, R: Reverse, A: Attractive, I: Indifferent

Berger et al. (1993) initially established a graph with two axes between 0 and 1. By including the reverse attributes in the satisfaction index (SI) and the dissatisfaction index (DI), negative values are incorporated in the SI axis, as shown in Figure 2-3.

A triangle incorporating values of M, I, and R is added to the initial four-quadrant graph to include the R attributes.

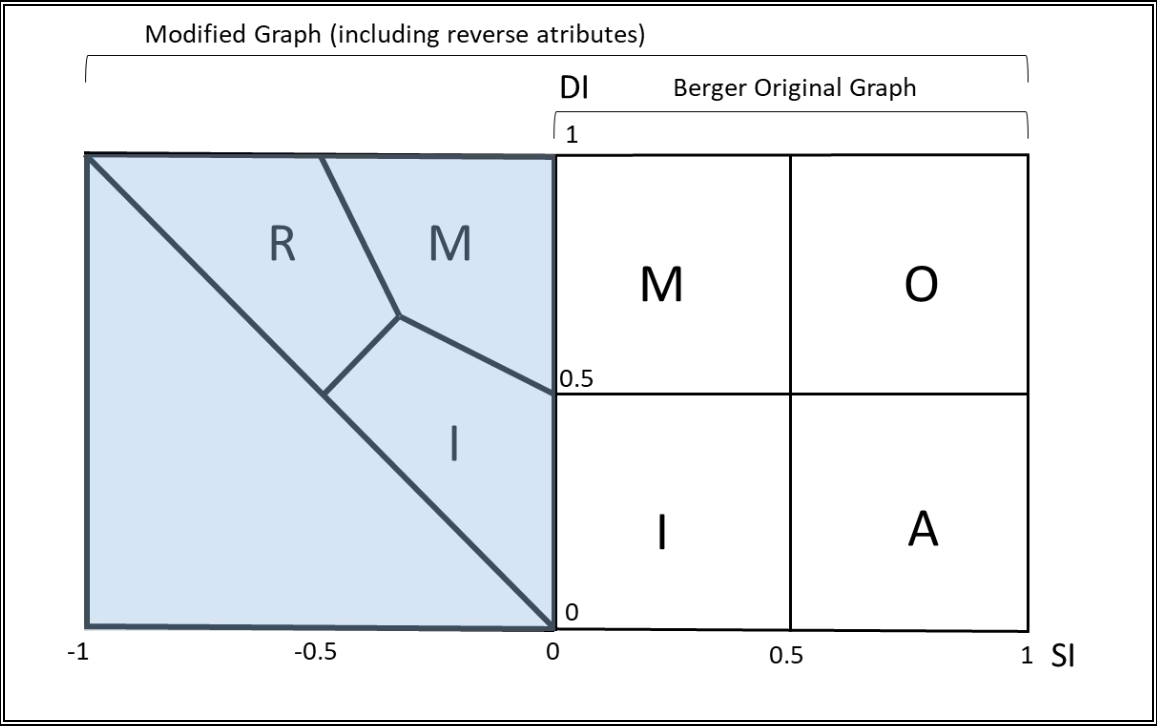
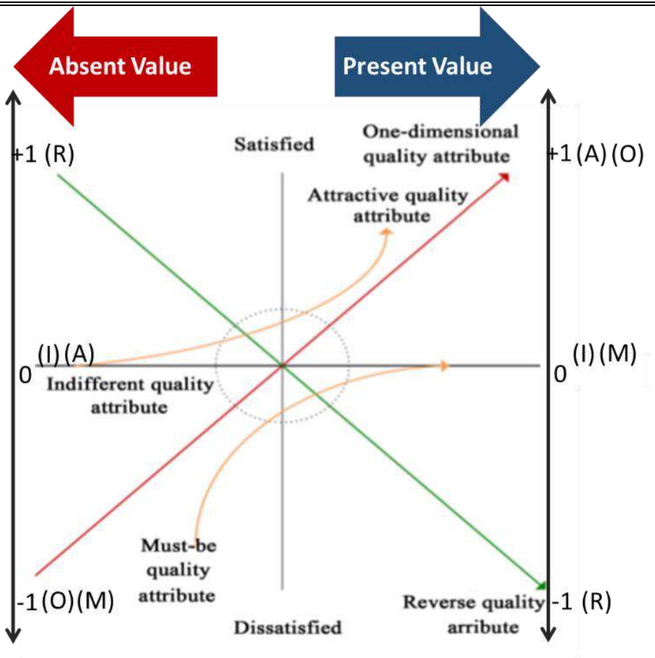



Figure 2-3. Modification of the Berger graph.

It is feasible that after using the CS, the values are in the limit between two types of attributes. If this happens, it is necessary to make a choice that must be made in the following order of priority: M > O/R > A > I. In other words, for example, if an attribute is on the boundary between A and I, it must be considered A.

d) Attribute Valuation

The attributes are related to value according to whether they are present or absent and their impact on customer satisfaction. A coding consisting of three values was applied: "−1" refers to customer dissatisfaction, "0" is neutral, and "+1" refers to customer satisfaction. Figure 2-4 (a) shows the valuations proposed in VAM for each attribute based on the behavior graph of Kano's attributes. A attributes have a value of +1 if they are present and a value of 0 if they are absent. O attributes have a value of +1 if they are present and −1 if they are absent. If present, M attributes do not add value (0), but if absent, their value is negative. I attributes do not add value regardless of whether they are present or not. R attributes are valued positively if they are absent (+1) and negatively if they are present (−1). All valuations are summed in Figure 2-4 (b).




(a)

| Attributes | Value | |
|---|---|---|
| | Present | Absent |
| M | 0 | -1 |
| O | +1 | -1 |
| R | -1 | +1 |
| A | +1 | 0 |
| I | 0 | 0 |

(b)

| Attributes | Expected | |
|---|---|---|
| M | presence | 0 |
| O | presence | +1 |
| R | absence | +1 |
| A | absence | 0 |
| I | - | 0 |

(c)

Figure 2-4. Attribute valuation. (a) Behavior chart of Kano's attributes with the proposed valuations in the model; (b) present and absent value by type of attribute. (c) Expected attributes.

e) Calculation of Indexes

The DVI refers to what the customer expects. To calculate the DVI, only what is expected by the customer should be considered. Figure 2-4(c) shows the values expected by the customer for each type of attribute. A is not expected, so it is expected that it is absent, and its value would be 0; O and M are expected to be present; I does not matter if it is present or not; and R is expected to be absent. The DVI is the sum of the products of the number of type attributes and their valuation (in expected presence or absence) divided by the total attributes (Equation 5). On the other hand, PVI refers to what the customer does not expect, it exceeds expectations. This model presents it as the sum of the DVI and percentage of A attributes (Equation 6). Figure 2-5 illustrates the calculation of the indexes using the same types of attributes as in the example in Table 2-4.

$$DVI = (M * 0) + (O * 1) + (R * 1) + (A * 0) / M + O + R + A + I \quad (5)$$

$$PVI = DVI + \%A \quad (6)$$

M: Must-be, O: One-dimensional, R: Reverse, A: Attractive, I: Indifferent

| Req | Quantity | | Value present | Value absent | Total | % |
|---|---|---|---|---|---|---|
| M | 3 | ✖ | 0 | | 0 | 30% |
| O | 3 | ✖ | +1 | | 3 | 30% |
| R | 1 | ✖ | | +1 | 1 | 10% |
| A | 1 | ✖ | | 0 | 0 | 10% |
| I | 2 | | - | - | 0 | 10% |
| | 10 | | | | 4 | |
| | | | | **DVI** | 4/10 | **0.40** |
| | | | | **PVI** | | **0.50** |

Figure 2-5. Example of index calculation.

### 2.3.3 Design Process—Value Generation

When the design process formally begins, value begins to be generated. Therefore, the generated value indexes can be calculated and compared with the indexes calculated in the requirements capture stage.

a) Generated Value Indexes (GVI) Calculation

Based on the list of attributes already classified, designers will decide on the inclusion of the attributes requested by customers throughout the design process. For this measurement, a questionnaire with the same list of attributes and a percentage scale of presence was incorporated. The resultant values are used to quantify the level of presence and absence of each attribute type, and based on the valuations of each type of attribute, GVIs are calculated, as shown in Equations 7 and 8.

$$DVG = (Ma*-1) + (Op*1) + (Oa*-1) + (Rp*-1) + (Ra*1) / M+O+R+A+I \tag{7}$$

$$PVG = (Ma*-1) + (Op*1) + (Oa*-1) + (Rp*-1) + (Ra*1) + (Ap*1) / M+O+R+A+I \tag{8}$$

M: Must-be, O: One-dimensional, R: Reverse, A: Attractive, I: Indifferent;
suffixes p = level of presence and a = level of absence

b) Comparison of Generated Value with Desired and Potential Value

Once the value generated is calculated, comparisons are made with the indexes established in the requirements capture. Figure 2-6 shows the relationships of requirements capture with value generation and identification of value losses and the relationship between the proposed value indices and the concept of value and attribute types. In order to obtain an initial value of "zero" as shown in the first bar, the M attributes must be fully met, since if they are not met or if they are not present, value is negative. Then, on this basis, the O attributes should be incorporated, and care should be taken to ensure that the R attributes remain absent to obtain the DVI. For the latter index, the A attributes are added to obtain the PVI. The I attributes do not add value.

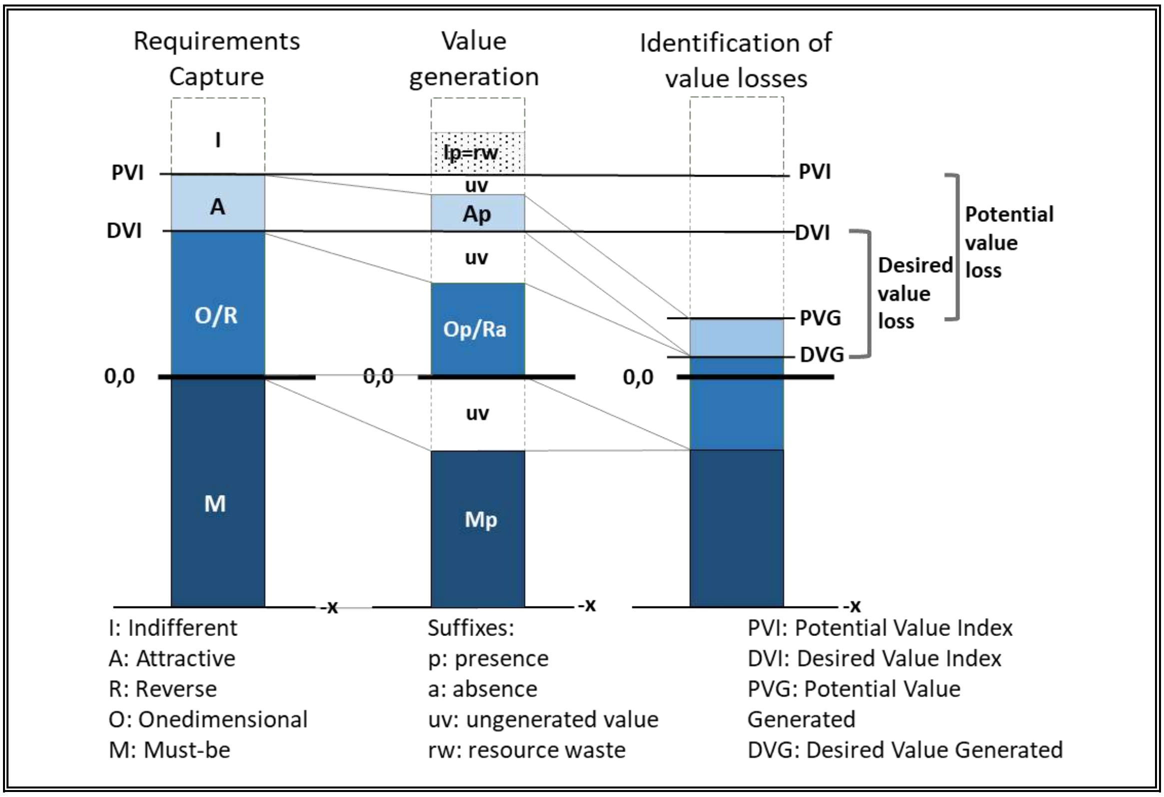



Figure 2-6. Relationships between the indexes, the attributes, and value losses.

Additionally, in the second bar, it is possible to observe the value generated in each of the types of attributes. The absence of M, O, and A represent ungenerated value, as well as the presence of R. On the other hand, when the I attributes are provided, they represent a waste of time, resources, and effort. Furthermore, two types of value losses are identified: (1) Those related to the desired value (such losses should be avoided completely); and (2) those related to the potential value (such losses could be avoided). Likewise, compliance percentages with value and loss of value of both the desired value and the potential have been incorporated to be used relatively and comparably. These key performance indicators (KPIs) are shown in Table 2-5 below.

Table 2-5. KPIs of the value generation process.

| | Value Losses | Percentage of Value Losses | Percentage of Value Fulfillment |
|---|---|---|---|
| **Desired Value** | DVL = DVI-DVG | $\text{DVLP} = \frac{\text{DVL}}{\text{DVI}}\text{x}100$ | $\text{DVFP} = \frac{\text{DVG}}{\text{DVI}}\text{x}100$ |
| **Potential Value** | PVL = PVI-PVG | $\text{PVLP} = \frac{\text{PVL}}{\text{PVI}}\text{x}100$ | $\text{PVFP} = \frac{\text{PVG}}{\text{PVI}}\text{x}100$ |
| DVI: Desired value index<br>PVI: Potential value index<br>DVG: Desired value generated<br>PVG: Potential value generated | | DVL: Desired value loss<br>PVL: Potential value loss | DVLP: Desired value loss percentage<br>PVLP: Potential value loss percentage<br>DVFP: Desired value fulfillment percentage<br>PVFP: Potential value fulfillment percentage |

### 2.3.4 Value Evolution Over Time

a) Determination of the Number of Revisions

The number of reviews of the value generated that will be made has to be established. These reviews can be incorporated in the project timeline frequently (weekly, fortnightly, monthly) or as milestones within the design process.

b) Comparison with Other Reviews

Over time, the value generated within the design process can change and ideally should increase. With the different revisions, one could observe how PVG and DVG vary, as well as the losses in value. Figure 2-7 shows the different design iterations shown through different reviews. This graph is a simile of target costing, in which the target cost and the allowable cost are initially set, and the aim is to achieve them by reducing the costs through design decisions. Likewise, the PVI, i.e., the best possible value, and the DVI, i.e., the minimum value accepted by the customer, were fixed before starting the design process, and the iterations seek to reach PVI and DVI.

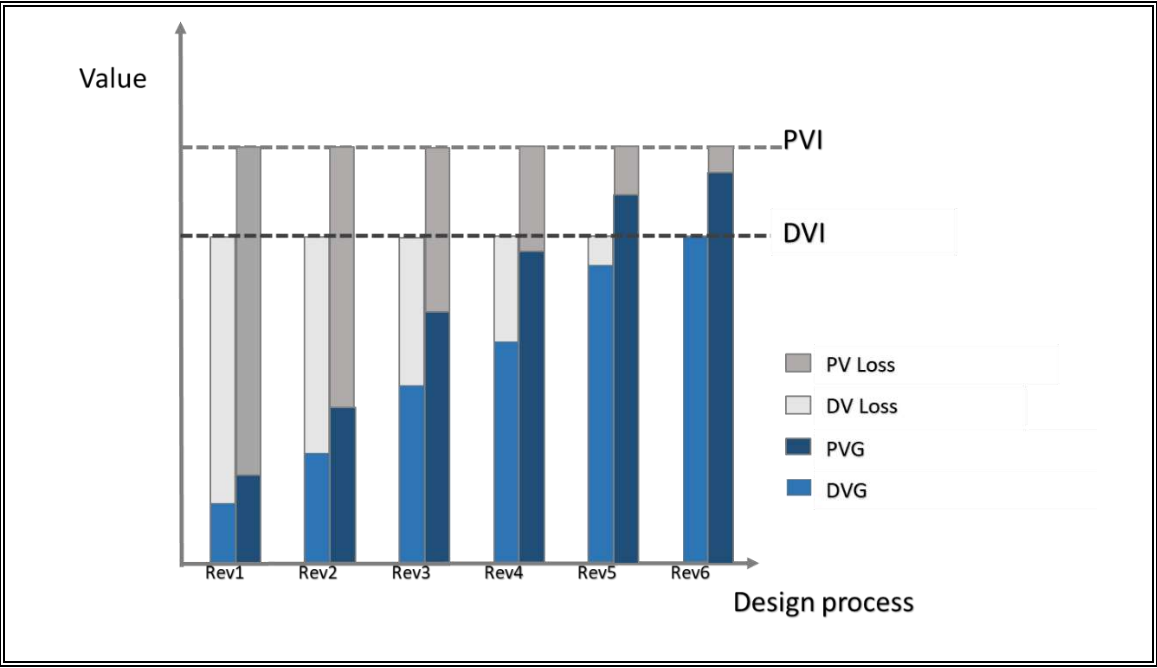



Figure 2-7. Value evolution over time.

### 2.3.5 Consideration of Multiple Customers

Design is an interactive and multidimensional effort that must represent the interests of several stakeholders (Bonnier et al., 2015). In the context of this research, value is defined as the fulfillment of the needs of different customers or stakeholders, considering their diverse visions. For this reason, each customer can determine the desired value and potential value, and these values are probably very different from those of other customers. The considerations of several customers are shown in Figure 2-8.

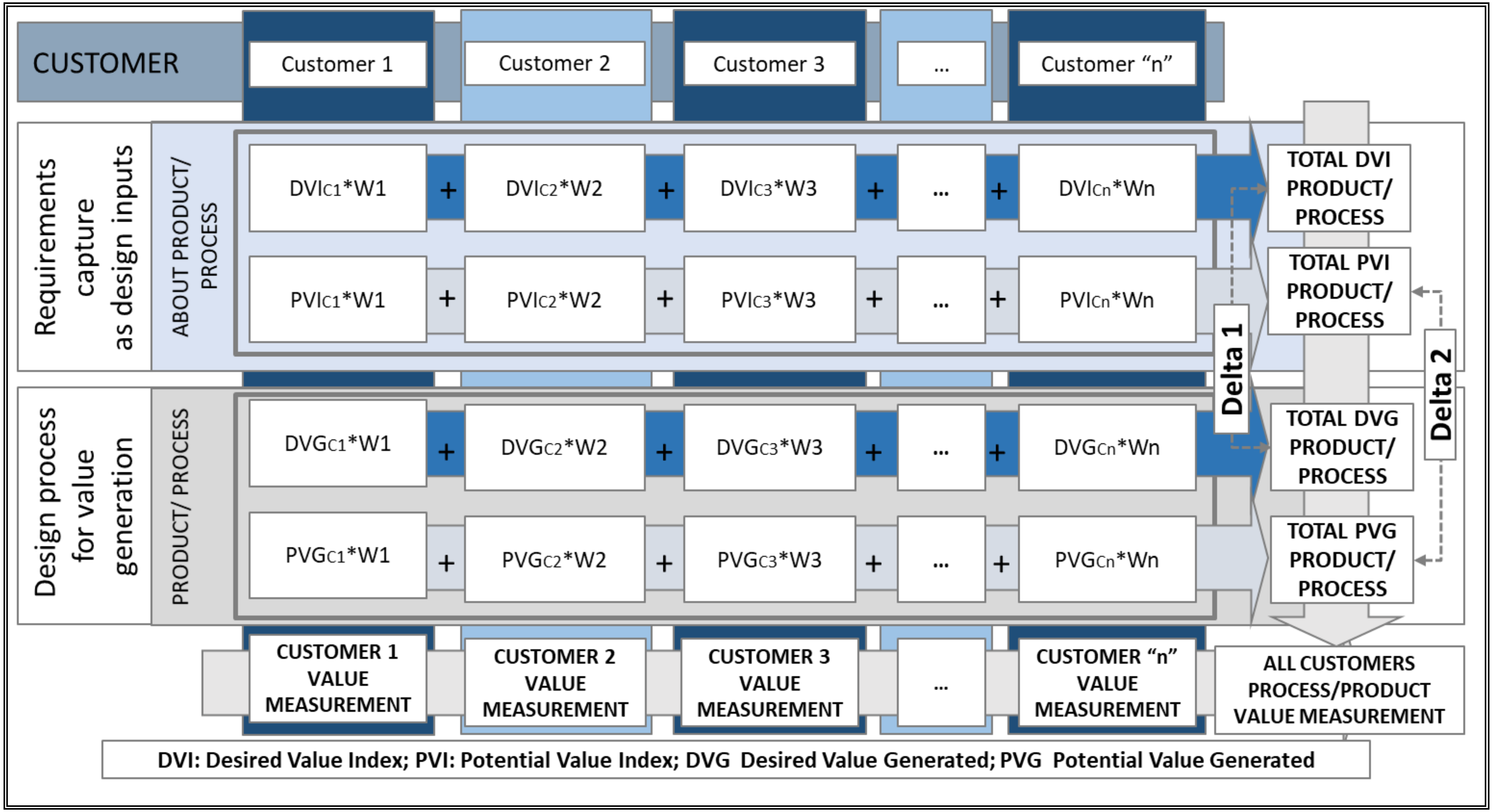



Figure 2-8. Complete VAM considering multiple customers.

Horizontally, as inputs for design, the requirements for the product or the design process of different customers are considered. In this sense, measurements result in total indexes of the product or process, both the desired and potential value of different customers. Likewise, throughout the design process, value is generated, which should respond to the requirements based on the desired value and could respond to the potential value.

For the calculation of these total indexes, a weighting factor (W) is established as the percentage value for each customer according to the importance given to the customer. The sum of all these Ws must be 1% or 100%, which will thus result in total indexes of desired value index (DVI), potential value index (PVI), desired value generated (DVG), and potential value generated (PVG) that amount to the total value of the product and of the process and that can be compared to each other. Vertically, the total value is measured by identifying the deltas between the total desired value and the total potential value concerning the total value generated of both the process and the product. Ultimately, the overall result of the model will be the total measurement of value concerning the whole design process and considering all customers.

## 2.4 ANALYSIS OF A PRACTICAL IMPLEMENTATION

The model was implemented in the first design stages of two projects of a real estate and construction company located in Santiago de Chile, whose primary activity is the integral execution of high-rise residential buildings. Project 1 and Project 2 were selected as case studies for their similar characteristics of scope, user profiles, and level of design progress, in addition to the researcher's access to the stakeholders involved.

VAM was applied to three customers (owner, designer, and builder) in three different aspects: Design process, product, and by-products in only one review. For this particular paper, the interest is to show how the practical application of VAM was performed, which is why only a part of the practical test will be shown below. The results that are shown refer specifically to how VAM works and what it can achieve.

Table 2-6. Attributes list of product

| **Attributes List** | |
|---|---|
| 1 | High percentage of repetitive elements |
| 2 | Low cost variability |
| 3 | Good cost/quality ratio |
| 4 | Good value for money/square meters |
| 5 | Good location |
| 6 | Sellable/competitive design |
| 7 | Aesthetic |
| 8 | Easy to build |
| 9 | Functional |
| 10 | Differentiating image |
| 11 | Innovative |
| 12 | Materials available on the market |
| 13 | Durable materials |
| 14 | Easy to install materials |
| 15 | Product stable to earthquakes and other events |
| 16 | Profitable product |
| 17 | Compliant with regulations |
| 18 | That meets the customer's requirements |
| 19 | To maintain its value over time |
| 20 | To improve the quality of life of the community |
| 21 | To improve the customer's quality of life |
| 22 | No reclaims |
| 23 | Presenting cutting-edge technology |
| 24 | Sustainable/energy efficient |

The product value measurement results are shown in Tables 2-6 and 2-7. Table 2-6 shows the attributes list, and on the table 2-7 illustrates the summary of the results of the product value measurement of the three customers in both projects. First, the perceptions of value of each customer differ; a higher DVI indicates that a customer expects more value than another with a lower DVI. However, the effort to meet this customer's expectations depends not only on the DVI but also on the percentage of M attributes as the basis. A DVI close to "zero" represents many M and/or I attributes, and a DVI close to "1" requires many O and R attributes (to be avoided), well above the number of M, I, and A attributes. On the other hand, a PVI with values close to the DVI means that few A attributes are identified, which can induce the need to innovate to include this type of attribute in the list.

Table 2-7. Product value measurement.

| | **Customer** | | | **Total** |
|---|---|---|---|---|
| | Owner | Designers | Builders | |
| w | 42% | 28% | 31% | 100% |
| DVI | 0.79 | 0.32 | 0.29 | 0.51 |
| PVI | 1.00 | 0.69 | 0.42 | 0.73 |
| | **Project 1** | | | |
| DVG | 0.10 | −0.11 | −0.11 | -0.02 |
| PVG | 0.22 | 0.14 | −0.04 | 0.12 |
| DVFP | 13% | −34% | −38% | −4% |
| PVFP | 22% | 20% | −10% | 16% |
| DVL | 0.69 | 0.42 | 0.40 | 0.53 |
| PVL | 0.78 | 0.55 | 0.46 | 0.62 |
| DVLP | 87% | 134% | 138% | 104% |
| PVLP | 78% | 80% | 110% | 84% |
| | **Project 2** | | | |
| DVG | 0.39 | 0.07 | 0.07 | 0.20 |
| PVG | 0.54 | 0.34 | 0.16 | 0.37 |
| DVFP | 49% | 23% | 24% | 40% |
| PVFP | 54% | 49% | 39% | 50% |
| DVL | 0.40 | 0.24 | 0.22 | 0.30 |
| PVL | 0.46 | 0.35 | 0.26 | 0.37 |
| DVLP | 51% | 77% | 76% | 60% |
| PVLP | 46% | 51% | 61% | 50% |

Second, even when these results were not expected, negative values were observed in the GVIs and, therefore, in the fulfillment percentages of desired or potential value, which means that the value loss is very high (more than 100%). In this case, the percentages of value losses incorporated facilitate understanding when negative value is generated.

In all cases, PVG is higher than DVG, which could be natural. However, this result means that even if the desired value has not been met in its entirety (M + O and avoiding R), efforts are being made to achieve A attributes, which shows that there is no clear prioritization of tasks.

This information confirms that the desired value of customers is not being generated. The next step consists of reviewing the compliance percentage of each type of attribute to determine which aspects of value are lost or generated. Table 2-8 illustrates in detail the generation of value in the design process for the designers in Project 2. The compliance percentages of attributes M and O are below those of attributes A and the same for attributes I, the latter representing a waste of resources and efforts in the compliance of attributes that do not generate value for the customer and confusing prioritization in the alignment of design objectives.

Table 2-8. Value generation in Project 2—process-designers.

| Process—Project 2 | | | | |
|---|---|---|---|---|
| Designer | | | | |
| | % Present | V. Pre | V. Abs | Score |
| M | 69% | 0 | −1 | −2.80 |
| O | 69% | 1 | −1 | 2.27 |
| A | 80% | 1 | 0 | 3.99 |
| I | 69% | 0 | 0 | 0.00 |
| R | | −1 | 1 | 0.00 |
| | DVL | 0.27 | DVG | −0.02 |
| | PVL | 0.31 | PVG | 0.14 |
| | DVLP | 109% | DVFP | −9% |
| | PVLP | 69% | PVFP | 31% |

It is also possible to establish comparisons between projects. In this case, two projects with similar characteristics within the same company are compared, which is why there is only one DVI and PVI by customer. Projects with a different DVI and PVI for the customer are possible. However, comparisons concerning the relative value generated and value loss can be made. Notably, Project 2 has created higher value than Project 1 (see Table 2-7), but it still has value losses that must be covered.

## 2.5 CONCLUSIONS

### 2.5.1 Summary

This paper identifies a gap in current practices in the value generation process in design within the AEC industry: There is a lack of adequate methods that link the suitable capture of customer requirements with the continuous measurement of the value generated as well as the timely identification of value losses at the time of design and not later, when it is no longer feasible to deal with them. A model is proposed to measure the value creation expected by customers and to identify value losses through indexes, which can help designers and project managers improve decision making within the design process, increase customer satisfaction and evaluate the allocation of resources to those activities that actually generate value.

### 2.5.2 Contributions

The proposed model responds to the need to measure the value creation expected by different customers within the design process through indexes of desired, potential, and generated value and the percentages of the fulfillment of desired and potential value. In addition, the model connects with the concept of value losses (Koskela, 2000) and contributes to the numerical and graphical identification of such losses. Likewise, it is capable of showing to interested individuals the aspects in which value is generated and other aspects in which it is partially or completely lost. The model supports a better understanding of the concept of value and how to capture it to support the conditions of customer satisfaction.

The VAM enables an integral view of the whole process encompassing the total measurement, considering the process, product, and customers. This vision can be incorporated for a particular aspect. Moreover, the percentage of incorporation of each type of attribute in design decisions provides clarity on the issues to which more significant efforts and resources should be allocated (to incorporate M and O attributes and to avoid R attributes), and the other aspects to which moderate efforts and resources should be allocated (incorporation of I attributes). Additionally, different comparisons can be made between different value visions of customers, the differences between the value generated by the process and product, the differences between the value generated in several projects, the differences between the value generated per customer, etc. In the same terms, it is possible to compare value losses per customer, per project, or between the process and product. On the other hand, it is possible to see the evolution of the value generated over time with several revisions.

The proposed model possesses certain flexibility and adaptability for diverse research needs. It can be applied in a specific area, for example, if there is a desire to evaluate what value is generated in terms of sustainability or security conditions or to choose which elements are the most attractive to the customer concerning the common areas of a building. Similarly, the value expectations of one target population can be compared to another, or how different design schemes or methodologies meet customer satisfaction conditions can be evaluated. Likewise, the evolution of the different indexes over time can be studied to reveal dynamic changes in customer preferences.

The development of the VAM contributes to knowledge since it responds to the challenge of defining and generating value in the design process, taking into consideration customers' requirements as process inputs. In addition, the VAM is based on influential factors for the generation of value and can show the impact of decisions or the use of methodologies on value generation or loss.

The model has practical value within the AEC industry. It is useful for optimizing products and processes since aspects for continuous improvement of the process are identified promptly by stages and by projects. It encourages constant feedback and has the potential to provide a higher delivery of value, as it makes it possible to determine the parameters that add value for different stakeholders, thereby informing designers where to direct resources and efforts to enhance vital variables and not trivial variables. In the VAM practical implementation, the design team considered the requirements of the builders in detail to improve the constructability and standardization of both projects, as well as the replacement of some elements and materials to make them optimal.

The VAM allows the observation of changes in value over time and how these changes align with the decisions made. Additionally, the model encourages conversations among key actors, makes it possible to think about value for the next customer in the process, and constitutes a contribution to adequately capturing requirements. In practical implementation, the professionals consulted considered VAM as a good tool for collaborative development, since it makes information and communication between the different stakeholders transparent, achieving clear requests from the early stages. A correct future implementation helps to have a differentiating element compared to other companies.

### 2.5.3 Limitations

The practical testing focused on two vertical building projects and was based on the experience of 20 professionals in building construction and design. Therefore, the results should not be interpreted as universal to all types of construction projects. However, the VAM is believed to be applicable to other sectors, such as housing, industrial construction, and infrastructure. In addition, when the model was tested, no consideration was given to the perception of value of the end user or the use of partial or total resources in increasing the value in the project.

### 2.5.4 Future Research

Opportunities for future research include the VA of other stakeholders, mainly end-users, as well as VA in other sectors of the AEC industry, not only vertical housing building. The possibility of continuously measuring value will be addressed in a further paper, which will incorporate not only different steps of the design process, but also other customers. The ability to capture the value perspectives of different stakeholders is a beneficial aspect of the VAM. However, these stakeholders are expected to present conflicting requirements, as their interests may be very different from each other; thus, the model can provide recommendations on how to weigh stakeholder requirements in the event of incompatibilities. It may be appropriate to include stakeholder mapping as support.

Concerning the resources used in the design process, the model shows how much effort and resources have generally been allocated to unimportant aspects, such as compliance with I attributes. The cost variable or the evaluation of the use of reallocation costs from less desirable to more desirable attributes could be added as a parallel axis.

# 3. EXPLORING VALUE GENERATION IN THE TRADITIONAL BUILDING DESIGN PROCESS: CASE STUDIES USING THE VALUE ANALYSIS MODEL

## 3.1 INTRODUCTION

Design is a systematic process for identifying, exploring, and exploiting value opportunities (Lee & Paredis, 2014). At this phase of the building life cycle, client requirements are translated into a design solution to provide the best value and the most cost-effective production (Rischmoller et al., 2006). The design process must deliver value to customers within their conditions of satisfaction, which typically concern cost, time, quality, and financial performance (Ballard, 2020; Eskerod & Ang, 2017). However, there may also be other value conditions such as sustainability, durability (Tommelein & Ballard, 2016), aesthetics/appearance, operation and maintenance, safety and environmental aspects, as well as potential benefits, such as problem and complaint management agreements or conflict resolution (Ballard, 2020; Palaneeswaran et al., 2004)

The nature of the design process is complex; it involves thousands of decisions, sometimes made over years with numerous interdependencies and under high uncertainty (Freire & Alarcón, 2002). The design process of projects is much more sophisticated than that of a single product because, instead of the satisfaction of an individual customer, it must consider the overall satisfaction of the large number of stakeholders involved (Khalife & Hamzeh, 2020).

The design process is considered iterative, linear, and segregated, with silos of knowledge and expertise, with fragmented, hierarchical, and controlled teams where information is not shared, with a high focus on cost, and with communication being mainly analog, two-dimensional, and paper-based (AIA, 2007; Czmoch &

Pękala, 2014; Leicht & Messner, 2007). However, in terms of design technologies and tools, the most widely used systems in the architecture, engineering, and construction (AEC) industry are two-dimensional computer-aided design (CAD) systems (Czmoch & Pękala, 2014; Singh et al., 2011). Although this way of working allows designers to create drawings with high precision and speed, it also generates an inherent need to consult two or more drawings several times to obtain a three-dimensional understanding, making it challenging to avoid interdisciplinary collisions (Czmoch & Pękala, 2014; Rischmoller et al., 2006). Other technologies may include the use of three-dimensional drawing programs without physical attributes or intelligent information (Jia et al., 2017). In terms of stakeholder participation in traditional design, the designer and owner are on the project from the predesign stage; some design consultants may be incorporated into design development, and the builder is incorporated into the construction stages (AIA, 2007; Manata et al., 2018).

The traditional building design process is considered the opposite of nontraditional methodologies (e.g., virtual design construction (VDC), building information modeling (BIM), and the design thinking model) or the process in new alternative delivery methods (e.g., integrated project delivery (IPD)). These nontraditional methods (e.g., VDC, BIM, IPD) are based on integrated and collaborative teams and concurrent and multilevel processes, are focused on best value, and utilize information and communications based on digital and virtual technology (AIA, 2007; Jia et al., 2017; Volkova & Jākobsone, 2016).

Several authors have written about the difficulties in generating value in traditional design and their effects in the construction stage, including reduced productivity, work program delays, and cost variability (Bustos, 2015; Love et al., 2014; Thyssen et al., 2010), or losses in other aspects more related to the design process itself (Ballard, 2011; Freire & Alarcón, 2002; Rischmoller et al., 2006). The literature affirms that the traditional design process in the AEC industry has been unable to meet customer value expectations (Gunby et al., 2013; Leinonen & Huovila, 2000; Pikas et al., 2020). Furthermore, conflicts between the distinct value perceptions of different stakeholders can affect value generation (Leung et al., 2002).

Value is usually measured in the final stage of the project through an objective perspective and by reviewing whether the cost and time objectives have been fulfilled (Khalife & Hamzeh, 2020). Understanding and then measuring value as the fulfillment of the client's needs are subjective, however. Transforming customers' subjective and ambiguous statements into measurable values is not a trivial endeavor; it requires logical processes and both qualification and quantification methods (Zhang et al., 2013). Nevertheless, there is a lack of indexes for comprehensively measuring value, that is, considering the adequate capture of the different perspectives of customer requirements and the timely identification of value losses (VL) at the time of design, not later, when it is no longer feasible to address such losses (Giménez et al., 2020). It is difficult to determine whether the value desired by the client has been met if it has not been adequately measured.

Thus, the present research aims to understand the generation and loss of value in the traditional design process by exploring how value generation responds to customer needs based on different conditions of satisfaction (i.e., cost, time and productivity) and by identifying VL in the design process and product. For this purpose, the authors apply the recently developed value analysis model (VAM) (Giménez et al., 2020) to fill this knowledge gap. It is expected that with the VAM application, value can be measured explicitly by identifying variations in customers' value perceptions and assessing whether this results in VL. The VAM uses the desired value index (DVI) and potential value index (PVI) to determine the value expectations of the different customers involved. The VAM also employs the generated value index (GVI) to measure perceived value and compares it to the DVI and PVI to determine VL as early as possible in the design process. This early identification of VL, as well as the value measurement for each customer separately and collectively, is one of the main reasons for the application of the VAM in this research.

This study addresses the following research question: How is value generated and lost in the traditional building design process? The authors explore this research question by answering the following two operational questions: (1) How does the traditional building design process respond to the needs of several customers with different conditions of satisfaction? and (2) What are the most frequent value losses? In this way, this paper contributes to applying a model of measurement and analysis of value to understand how the building design process responds to customer needs and what conditions of satisfaction can be visualized for more significant value generation. Additionally, it contributes by identifying value losses as a result of the differences between the interests of multiple customers as well as the proportion of these losses among all losses caused by project performance. Value losses that are identified in the design stage can be anticipated and corrected in time. This early identification can optimize value generation in the design process, avoiding or reducing VL and maximizing value.

## 3.2 BACKGROUND

Traditionally, value generation is related to achieving the goals of a project or to fulfilling the real purpose of its implementation (Tillmann et al., 2013), as well as the evaluation and analysis of performance based on cost, time and quality indicators (Fong et al., 2007; Munthe-Kaas et al., 2015). However, current views consider the iron triangle (cost, time and quality) insufficient, reformulating it to strike a balance in how performance is measured and incorporating a value-centered vision (Fong et al., 2007; Winter & Szczepanek, 2008). This vision includes aspects related to people, products and resources such as customer satisfaction, project team satisfaction, technology and the environment (Chang et al., 2013; Lin & Shen, 2007) Different value concepts with similar approaches have been presented in the literature. All these definitions can be summarized as the relationship between the satisfaction of multiple customer needs considering their diverse visions, the dynamism of value over time, the type of project, and the use of required resources (Drevland et al., 2018; Eskerod & Ang, 2017; Novak, 2012). Value is often associated with monetary value, representing the economic view of market exchange value (Riis et al., 2019; Thyssen et al., 2010). However, it is essential to distinguish between cost (economic or monetary value) and value. Things can have significant aesthetic, sentimental, scientific, moral, political, or personal value but have little or no economic value, and vice versa (Benedikt, 2006).

According to Giménez et al. (2020), the influential factors within the value-generation process are related to (1) minimization of the life cycle cost; (2) the pursuit of the satisfaction of customer needs; (3) integrated solutions for the fulfillment of requirements; (4) requirement capture and flow-down; (5) assurance of the capacity and performance of the production system; (6) verification that the requirements are met; (7) value measurement through metrics; and (8) the identification of VL. These factors result from integrating several value perspectives (Koskela, 2000; Leinonen & Huovila, 2000; Zhang et al., 2016).

Additionally, the simultaneous development of the process and the product is considered an opportunity to generate value (Khan et al., 2011; Mandujano et al., 2016). Value is maximized when needs are accurately determined and those needs are maximally satisfied by the product produced and the process employed to produce it (Ballard & Zabelle, 2000). Furthermore, several authors have written about the difficulties in generating value in traditional design (Gunby et al., 2013; Leinonen & Huovila, 2000) and how they affect productivity, quality, and buildability (Bustos, 2015; Love et al., 2014; Reifi & Emmitt, 2013) or lead to losses in other aspects more related to the design process itself (Ballard, 2011; Freire & Alarcón, 2002; Rischmoller et al., 2006).

The design process is, by nature, complex (Freire & Alarcón, 2002); furthermore, its characteristics do not apparently contribute to the successful generation of value in projects. In the traditional model, the design process is separate from the production stages and is generally focused on understanding customer needs to generate a complete project; its performance is evaluated on criteria such as cost (Díaz, 2017; Talebnia et al., 2017). Consequently, after the cost estimate, the project must be redesigned to fit the budget, which leads to project delays, conflicts, ambiguities, and value loss (Ballard, 2006). The design process traditionally does not consider minimizing waste and resource use (cost) during the construction stage (Rischmoller et al., 2006). According to Freire & Alarcón (2002), the design process suffers from ignorance of client requirements, bureaucracy and paperwork, poor interdisciplinary coordination, the unavailability of information, and rework. Additionally, a considerable amount of time and effort is spent trying to understand and drive client requirements; there are many assumptions, contingencies, and schedule pressures (Rischmoller et al., 2006). Projects delivered in the traditional model suffer because participant success and project success are not necessarily aligned (AIA, 2007).

This literature review shows that the traditional design process does not generate the value expected by the client, regardless of whether it has been quantified or not. Although there may be indicators that successfully measure the performance, time and costs of a project, when it comes to customer or project team satisfaction, there does not appear to be quantitative evidence that demonstrates the difficulty of achieving value. Therefore, the present research aims to understand the generation and loss of value in the traditional design process, explore how value generation responds to customer needs based on different conditions of satisfaction and identify the most common VL.

## 3.3 RESEARCH METHOD

### 3.3.1 Overall approach

The research strategy is quantitative and based on case studies. The case study approach is a useful methodology because it investigates a contemporary phenomenon within its real-life context without manipulation (Yin, 2003); it identifies patterns and the causes of phenomena and provides data to evaluate processes, programs, individuals, or environments (Hernández et al., 2014). According to Yin (2003), the research design components in case studies are study questions, study propositions, units of analysis, linking data to propositions, and criteria for interpreting the case study.

This study addresses the following research question: How is value generated and lost in the traditional building design process? The authors explore this question by answering the following two operational questions: (1) How does the traditional building design process respond to several customers' needs under different conditions of satisfaction?; and (2) What are the most frequent VL?

The literature review demonstrates that the traditional design process does not generate the value expected by the client in aspects related to performance, time or costs. However, with regard to other conditions of customer or project team satisfaction, there does not seem to be quantitative evidence that demonstrates this difficulty in achieving value. The present research aims to understand the generation and loss of value in the traditional design process, explore whether the client's needs are actually met based on different satisfaction conditions and identify the most common VL. The proposition is to verify quantitatively the low value generated by the traditional design process. It is also thought that the most significant VL is not due to differences in evaluation criteria of different customers but to the performance of the project itself.

The unit of analysis is the project, which must be able to respond to its customers' needs and requirements. This article presents research based on a multiple-case study of three traditional housing design projects. The number of cases has been decided among the researchers. Initially, a single case study was proposed, but it was later decided that using three case studies applied to different contexts would generate more robust results that could be transferable to other projects.

As stated in the Introduction, the authors apply the recently developed VAM (Giménez et al., 2020) for case study analysis. This model is based on the theory of attractive quality (Kano et al., 1984) and target cost (Tanaka, 1993) to understand and monitor value creation during the design process. Data are collected in three cases through interviews, focus groups, and surveys to obtain information on both the product and the design process. The goal is to quantitatively analyze the value attributes of the traditional residential construction process and product design from different clients' perspectives.

This research presents the results of the three case studies. The first was used as a project to validate the VAM (Giménez et al., 2020) and as a pilot project to refine the data collection instruments (Yin, 2003) and determine how best to proceed to answer the proposed research questions.

### 3.3.2 Overview of the case studies

The case studies analyzed in this paper correspond to three traditional housing design projects in three different countries to evaluate the design product and process. These projects are selected based on their different characteristics of scope and typology, user profiles, customer types, the relationship between owner and construction company, and level of design progress, in addition to the researchers' access to the stakeholders involved. Furthermore, these case studies present the general characteristics of the traditional building design described above—a fragmented process and team, unshared information, and analog communication.

The case studies should have the traditional way to deliver projects: Design and construction separately, but without public bidding restrictions, so the researcher chose private projects. Also, It was required data related to involved customers: owners, designers and builders, and ideally, end-users; and that these should have different characteristics in each project (owner's experience, type of design firm, type of construction company and its integration relationships, and socio-economic level of the end-user).

The level of analysis was simultaneous and individual and then collective. Table 3-1 depicts the characteristics of the three selected projects.

Table 3-1. Case study characteristics

| Case study | Type | Socioeconomic level | Design process status | Housing units |
|---|---|---|---|---|
| 1. Chile | High-rise building | Lower-middle income | Preliminary design | 252 |
| 2. Spain | Single-family housing | High income | Under construction | 1 |
| 3. Venezuela | Multifamily housing | Higher-middle income | Last phase: under construction | 250 |

Case study 1 (CS1) is a project in the preliminary stages of the design process. It consists of 252 housing units, delivered in one residential building of 15 floors and two underground levels, to meet the needs of people at the lower-middle-income level. This project is being carried out by a real estate and construction company located in Santiago, Chile, whose main activity is the integral execution of high-rise residential buildings.

Case study 2 (CS2) is a high-income, single-family project located in Valencia, Spain. The project is in the construction stage; thus, the design is already completed. The owner separately contracted the design and the construction. Hence, an architectural studio designed the single-family house, and then a constructor built it.

Case study 3 (CS3) is a multifamily housing project for a higher middle-income target. It is being built in six development phases and is located in Barquisimeto, Venezuela. It consists of 250 housing units delivered in two types of residential buildings: townhouses and low-rise buildings. Five development phases are already inhabited, and the sixth phase is under construction. The design and construction are being carried out by a real estate construction company whose main activity is the execution of residential buildings.

### 3.3.3 Data collection

Data collection was conducted through interviews, focus groups, and surveys. Table 3-2 lists the different stakeholders consulted per case. In the first two cases, the entire data collection process was conducted in person. Due to the 2019 coronavirus disease (COVID-19) pandemic, for the third case, data collection was conducted online through virtual interviews and online surveys sent by email. The objective of the interviews and focus groups was to establish a list of attributes adapted to the projects' process and product. The objective of the surveys was to understand how the clients see the attributes and classify them and to understand the level of development of the requirements.

Table 3-2. Case study data collection

| Case study | Owner | Designer | Builder | End-User |
|---|---|---|---|---|
| 1. Chile | Interview and survey | Focus group and surveys | Focus group and surveys | Not consulted |
| 2. Spain | Interview and surveys | Interview and surveys | Interview and surveys | Interview and survey |
| 3. Venezuela | Online interview and surveys | Online interview and surveys | Online interview and surveys | Online survey |

In CS1, data were collected mainly through surveys and focus group meetings. Eight professionals from the company's different technical areas and three customers (the owner, designer, and builder) participated in the data collection process. Because the project was still in the preliminary design stage, it was not possible to incorporate end users. In CS2, data were obtained through interviews and questionnaires with the owner, two architects from the architectural firm, and two construction engineers from the construction company. In CS3, online (due to the COVID-19 pandemic) interviews and questionnaires were conducted with the owner, an architect, two construction professionals, and 58 end users; four sales professionals served as links with the projects' end users.

It is essential to highlight the differences in the characteristics of the 3 cases. In CS1 and CS3, the owner is the real estate company that requests the project's design and construction; they are represented by a director or group of people who are part of the company's management. These owners have experience in developing real estate projects. In CS2, the owner is a person (or a family) who hires the services of the architectural firm and the construction company only once; therefore, the owner has no experience in the execution of projects. On the other hand, CS1 does not incorporate the end user in the research, which is why CS2 is included in the study to understand the expected value of the end user; however, in this case, the end user and the owner are the same. In CS3, the owner is a different entity than the end user.

### 3.3.4 Data analysis

The VAM proposed by Giménez et al. (2020) was applied in each of these three case studies to measure customer value in three main stages: requirement capture, value generation, and comparison. Figure 3-1 summarizes the stages and steps of the VAM, which are explained below.

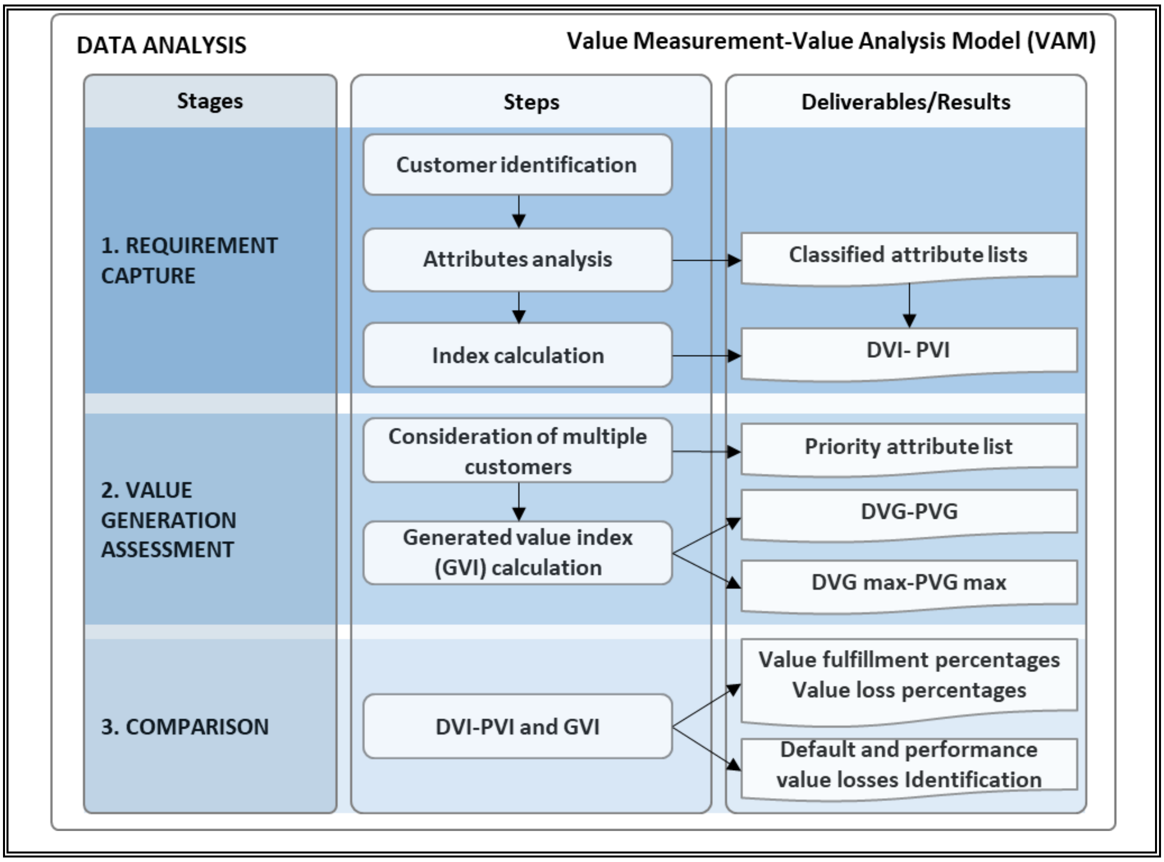



Figure 3-1. Stages and steps of the VAM

Stage 1: Requirement Capture. The design team needs to identify the principal customers and analyze each customer's required attributes to calculate the DVI and PVI.

Stage 2: Value Generation Assessment. The different perceptions of customers are considered to establish how each attribute must be dealt with. The maximum possible value that can be generated is established based on this prioritization, and two forecast indexes, the maximum desired value generated index (DVG max) and maximum potential value generated index (PVG max), are identified. Subsequently, the actual generated value indexes, the desired value generated index (DVG) and potential value generated index (PVG), are calculated based on the degree of presence of the attributes in the design process and product.

Stage 3: Comparison. The DVI and PVI initially calculated are compared to the GVIs in the design process. In the following section, the VAM is explained in detail.

## 3.4 VALUE ANALYSIS MODEL

The VAM (Giménez et al., 2020) uses the theory of attractive quality (Kano et al., 1984) and target cost (Tanaka, 1993) as reference points. It measures the generation of value expected by clients and identifies VL based on indexes of desired, potential and generated value, identifying VL and value-fulfillment percentages in the design-build process. In this section, the VAM is explained in detail.

### 3.4.1 Stage 1: Requirement capture

a) Customer identification

The different customers present in the process are identified and then selected for evaluation. Value measurement must be performed separately by customers or by groups of customers. In the case studies selected for this research, the following customers were evaluated: designers, builders, end users, and owners.

b) Attribute analysis

This analysis includes creating a list of attributes based on customer requirements and then classifying them according to the five types of attributes proposed by Kano et al. (1984). Based on the design process or product, this list must represent each client's standards, wishes, and needs.

The attribute lists were elaborated based on the customer's needs regarding the design process and product in each project. Elaborating these lists was an iterative interview process with open-ended questions, followed by reviews, additions, and exclusions until the final lists by type were obtained. The customers defined attributes and the satisfaction conditions for the design process and product. The process satisfaction conditions were time, cost, integration, information flow, deliverables, technology, constructability, corporate environment, conflicts, and responsibilities. The product satisfaction conditions were attributes related to home comfort, performance, community comfort, finance and investment, aesthetics, innovation, technology, health, and sustainability.

A two-dimensional questionnaire was prepared to classify each attribute. The first question was functional: How do customers feel if the proposed characteristic is provided? The second question was dysfunctional: How do customers feel if the intended characteristic is not provided? Each question (whether functional or dysfunctional) had five response options: like, must-be, neutral, live with, and dislike. In this way, the attributes were classified as must-be (M), one-dimensional (O), reverse (R), attractive (A), and indifferent (I) attributes based on the combination of answers to the two questions. Kano et al. (1984) define attributes as follows (Horton & Goers, 2019; Huang, 2017):

1) A “M” attribute is an essential requirement. Its absence leads to extreme customer dissatisfaction; the customer takes this requirement for granted. Therefore, it does not increase customers' satisfaction level when it is met. Meeting this requirement leads to a state of not being dissatisfied.

2) An “O” attribute is a linear kind of requirement. When it is met, customer satisfaction increases. However, when it is unmet, customer satisfaction decreases. These attributes are what customers expect from the proposed product/service. They can be thought of as "the more, the better" characteristics. They are also referred to as performance or satisfier attributes.

3) “A” attributes generate a great amount of satisfaction if they are present. However, since customers do not expect them, they generate no feeling if they are absent. They are also called delighters, exciters, or surprising qualities.

4) An “I” attribute is a no-preference requirement, implying that the customer is indifferent to the requirement/feature. Customers do not care if the attribute is present or not.

5) “R” attributes are product attributes that customers dislike. The presence of these attributes causes customer dissatisfaction, and their absence causes satisfaction. They can be thought of as characteristics for which "the fewer, the better."

c) Index calculation

Customers must value each type of attribute to calculate the DVI and PVI. The attributes are related to value based on whether they are present or absent and their impact on customer satisfaction. A coding consisting of three values was applied: "-1" means customer dissatisfaction, "0" means neutral, and "+1" means customer satisfaction. Table 3-3 shows the valuations proposed in the VAM for each behavioral attribute.

Table 3-3. Attribute valuation

| Attributes | Value | |
|---|---|---|
| | Present | Absent |
| M | 0* | -1 |
| O | +1* | -1 |
| R | -1 | +1* |
| A | +1 | 0* |
| I | 0 | 0 |

* expected by the customer

M attributes have a value of 0 if they are present and -1 if they are absent. O attributes have a value of +1 if they are present and -1 if they are absent. R attributes are positively valued if they are absent (+1) and negatively valued if they are present (-1). If A attributes are present, they have a value of +1, but their value is zero (0) if absent. I attributes do not add value regardless of whether they are present or not. To calculate the DVI, only what is expected by the customer should be considered. Table 3-3 shows the values expected by the customer for each type of attribute represented by asterisks (*). A attributes are not expected; that is, they are expected to be absent, and their value should be 0. O and M attributes are expected to be present. It does not matter if I attributes are present or not, while R attributes are expected to be absent. The DVI is the sum of the products of the number of attribute types and their valuation (expected presence or absence) divided by the total attributes. The PVI refers to the best possible value that can be obtained. In this model, the PVI is the sum of the DVI and the percentage of A attributes. The calculations of both indexes (DVI and PVI) are shown in Equations 1 and 2, respectively.

$$DVI = (M*0)+(O*1)+(R*1)+(A*0)/M+O+R+A+I \quad (1)$$

$$PVI = DVI + \%A \quad (2)$$

M: must-be, O: one-dimensional, R: reverse, A: attractive, I: indifferent

### 3.4.2 Stage 2: Value-generation Assessment

a) Consideration of multiple customers

In the context of this research, value is defined as the fulfillment of the needs of different customers or stakeholders, considering their diverse visions. For this reason, each customer involved in the project determines the desired value and potential value and has a unique index of desired and potential value, different from those of the other customers. The diversity in these indexes is the result of the differences in customers' classifications of the attributes. According to (Horton & Goers, 2019), each attribute type has a customer effect that must be dealt with based on a business decision; this decision, in turn, is related to the optimal degree of presence of a particular attribute. They are summarized in Table 3-4.

Table 3-4. Summary of attribute perspectives based on Horton & Goers (2019)

| Attribute | Customer effect | Business decision | Optimal level of presence |
|---|---|---|---|
| M | Fulfill | Must-be | 100% |
| O | Satisfy | Increase | 100% |
| R | Displease/Repel | Avoid/Decrease/Remove | 0% |
| A | Delight | Invent | Between 0% and 100% |
| I | Do not care | Unnecessary-Superfluous | 0% |

Two types of prioritization can be applied to consider how each type of attribute will be treated under different customer views:

1. Weighting factor. Priority is given to treating the attribute based on the customer who has the highest weighting factor (W). For example, if an attribute was rated O by a customer with W=40%, I by a customer with W=25%, and M by another customer with W=35%, then the attribute should be treated as O.

2. MORAI criterion. The priority of attributes is established based on the following order: M > O/R > A > I (Berger et al., 1993; Giménez et al., 2020). In the same example above, the attribute should be treated as M.

The authors recommend combining both forms of prioritization, first using the MORAI criterion and then, if necessary, using the W. In cases where there are conflicts between O and R (which are at the same level of the MORAI criterion), the W is used to decide how the attribute should finally be prioritized. The use of the MORAI criterion favors the alignment of all clients' interests toward the optimal level of presence, benefiting the optimization of the project. W was determined collaboratively based on the customer's importance, impact or knowledge of the product or process. For example, the end user will have more weight in the product than in the internal design process.

b) Generated value index (GVI) calculation

Based on the prioritization of the attributes, the maximum possible value that can be generated per client is established. When value must be generated for a single customer, 100% of the desired and potential value can be achieved. However, when considering different customers, perceptions may vary; thus, it may not be possible to generate total value for all customers. Decisions may have to be made about which customer preferences should be privileged over others.

For example, if an attribute was classified as R by one customer but was classified as O and M by other customers, then it should be dealt with as M based on the MORAI criterion. In this case, the optimal level of presence will be 100%, whereas for the customer who considers it R, there will be a value loss. Even before starting the design process, these VLs can be determined and measured after deciding how each attribute will be dealt with. Based on the differences between each customer's classification and the optimal level of presence of the attributes (100% presence for M, O and A, and 0% presence for R and I) after prioritization, it is feasible to measure the DVG max and PVG max.

A questionnaire with the list of attributes is used to quantify the degree of presence or absence of each attribute. The DVG and PVG are calculated based on the valuations of each type of attribute (see Table 3-3), as shown in Equations 3 and 4.

$$DVG = \frac{(Ma * -1) + (Op * 1) + (Oa * -1) + (Rp * -1) + (Ra * 1)}{M + O + R + A + I} \quad (3)$$

$$PVG = \frac{(Ma * -1) + (Op * 1) + (Oa * -1) + (Rp * -1) + (Ra * 1) + (Ap * 1)}{M + O + R + A + I} \quad (4)$$

M: must-be, O: one-dimensional, R: reverse, A: attractive, I: indifferent, p: level of presence, and a: level of absence

### 3.4.3 Stage 3: Comparison

The DVI and PVI initially calculated are compared to the GVIs in the design process. The result of this comparison will be the measure of the generation and loss of value in the design process and product. Furthermore, two types of VL are identified: (1) those related to the desired value (such losses should be avoided) and (2) those related to the potential value (such losses could be avoided). On the other hand, comparing the DVG and PVG to the maximum possible value identifies two types of VL: (1) those based on the differences between the perspectives of the clients (default VL) and (2) those that are a consequence of the actions or decisions of the project (performance VL).

Figure 3-2 is based on Giménez et al. (2020) and illustrates the initial value indexes, the GVIs in the design process and the VL. This paper incorporates default and performance VL, both desired and potential value loss.

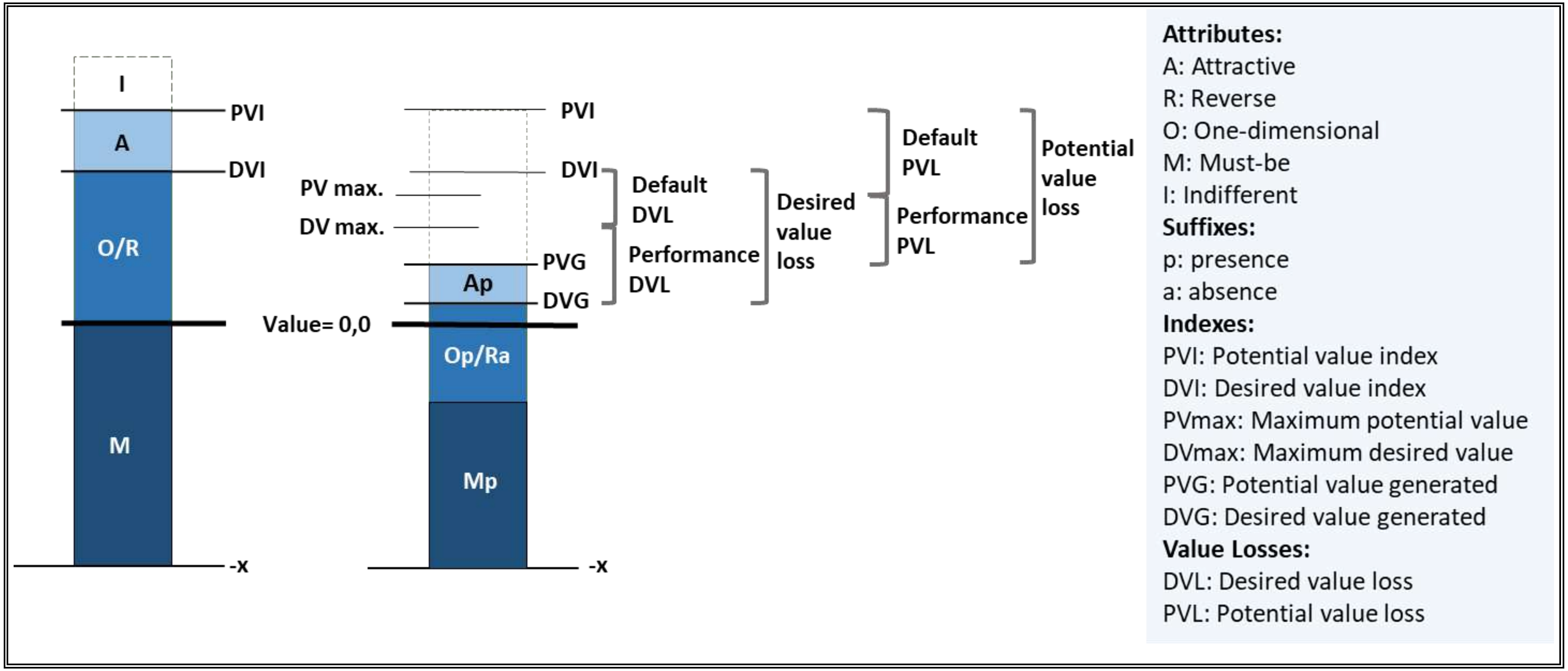



Figure 3-2. Comparison of the generated value indexes with desired and potential value

## 3.5 RESULTS AND DISCUSSION

This section presents the value expectations, and the generation and loss of value due to the evaluation of the three case studies, individually and then comparatively. It also reviews the order of priorities that customers have concerning the value attributes of the projects. Subsequently, value analysis is performed according to the satisfaction conditions of the process and product.

In summary, the case studies illustrate the application of the VAM and present examples of traditional design process behavior in private housing projects. The VAM supports a better understanding of the concept of value and how to capture it to support customers' satisfaction conditions. The VAM provides a comprehensive view of the entire process that encompasses total value measurement, considering the process, the product, and multiple customers. Based on these results, design decisions can be made with regard to incorporating essential and valuable attributes and not incorporating attributes that are irrelevant to customers based on the allocation of project resources.

### 3.5.1 Generation and loss of value for customers

The values generated per customer are compared to the value expectations in both the process and the designed product, resulting in percentage values. This section also shows the VL, which represents the potential or desired value not provided, and the "W" for each client of the three case studies. In each case study, customers were identified. All interviewees established weights (percentages) based on the importance of each customer; the average of the different percentages was used as the "W" for each customer.

Table 3-5. Weighting factor (W) for customers

| | Owner | | Designer | | Builder | | User | |
|---|---|---|---|---|---|---|---|---|
| CS1 | 41.6% | | 27.6% | | 30.8% | | - | |
| CS2 | 25% | | 25% | | 25% | | 25% | |
| | Product | Process | Product | Process | Product | Process | Product | Process |
| CS3 | 31.6% | 39.3% | 16.6% | 25.9% | 14.0% | 31.2% | 37.8% | 3.6% |

Table 3-5 shows the W for each customer per case study. In CS1 and CS2, the W is equal for the product and the process; in CS3, the interviewees differentiate each customer's importance in the process and product. For example, the end user is more important in the product than in the process. In CS2, the interviewees considered that the four customers had the same importance. However, it is essential to highlight that the owner is the same end user, so if it is seen as unified, this "owner-user" would have 50% importance. In CS1, the end user was not considered, as explained above.

Table 3-6 shows the total value expectations of the three projects, taking into account each index with the respective customer's W. The expectations of product value (DVI and PVI) decrease as the socioeconomic level increases. According to Borgianni (2018), Kano's model is dynamic; thus, it is expected that one type of attribute will become another (A attributes will become O and then M requirements) over time or as the clients accumulate experience. The same phenomenon can be observed in process expectations, in the sense that the DVI and PVI decrease when there is more experience in the field or there are more opportunities in the context. In Annexes 3-1 and 3-2, it is possible to observe the classification of each attribute by case study.

Table 3-6. Value expectations by case study

| | Process | | | Product | | |
|---|---|---|---|---|---|---|
| | CS1 | CS2 | CS3 | CS1 | CS2 | CS3 |
| DVI | 0.21 | 0.33 | 0.46 | 0.49 | 0.21 | 0.33 |
| PVI | 0.38 | 0.67 | 0.64 | 0.72 | 0.33 | 0.51 |

Figure 3-3 illustrates the results of the process value analysis in the three cases studied, showing the percentages of value generated and value lost for each case and each client. The value generated is insufficient for all customers: the DVG percentages vary between -135% and 10% and between -36% and 32% in PVG. In most cases, DVG and PVG obtained negative values, or when they obtained positive values, they were deficient (less than 33%). Negative results mean that the most important attributes (M and O) are not fully incorporated or that the R attributes are not adequately avoided.

Desired Value Losses (DVL) are generally higher than 100%. DVL percentages vary between 184% and 235% in CS1, 90% and 120% in CS2, and between 107% and 129% in CS3. VL is understood as the portion of value not provided, even if potentially possible (Koskela, 2000). The value to be provided is 100% of the DVI (desired or expected value) and, ideally, 100% of the PVI (potentially possible). The PVL varies between 115% and 136% in CS1, 68% and 85% in CS2 and 97% and 129% in CS3. In CS1, the most significant losses correspond to builders, in CS2 to designers, and in CS3 to end users. These results are interesting since the highest VL coincides with the client with the lowest W. In CS1 and CS2, it also coincides that the client with the highest W is the one that receives the highest value. It is noteworthy that CS1 generated less value, which may be because it is at an early stage of the project (preliminary design), therefore, its process attributes were less developed than what they would have been in the construction or full design stages.

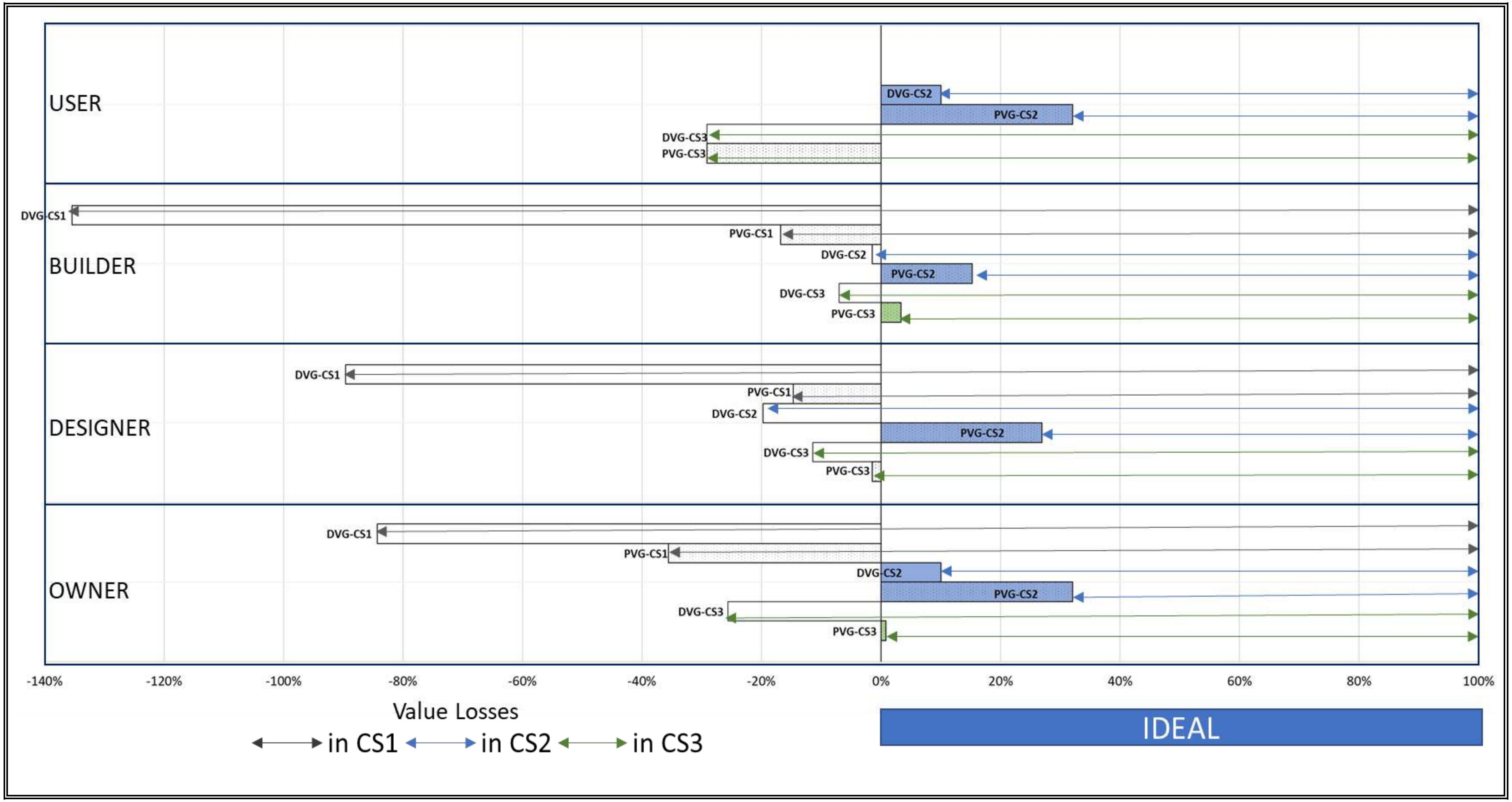



Figure 3-3. Value generated and value losses for customers in the process

Figure 3-4 shows the percentages of value generated and value lost for each case and each customer in the product. The value generated in the product is also insufficient for all customers but is nevertheless higher than that generated in the process. The values vary between -43% and 60% in DVG and between 6% and 73% in PVG. DVG and PVG obtained positive values; only three negative values were observed (two in CS1 and one in CS3). Each case has a different desired value generation, between -30% and 15% in CS1, 44% and 60% in CS2, and between -43% and 10% in CS3. DVL is generally less than 100%, and the values vary between 85% and 130% in CS1, 40% and 56% in CS2 and 90% and 143% in CS3. PVL varies between 75% and 94% in CS1, 25% and 41% in CS2 and 67% and 80% in CS3. The most significant losses for CS1 and CS3 correspond to designers and in CS2 to builders. In CS1 and CS2, the customer with the lowest W coincides with suffering the highest loss of value; in CS1 and CS3, the customer with the highest W coincides with receiving the highest value. There may be some relationship between W and value generation.


Figure 3-4. Value generated and value losses for customers in the product

Figures 3-3 and 3-4 show that the greatest losses are found for the desired value rather than for the potential value. As discussed above, the desired value must be fulfilled, whereas the potential value is optional. If the PVL had been more significant than the DVL, it would be expected, yet meaningless, although the results are the opposite. These results support the preliminary ideas regarding the difficulty of the design and construction industry in effectively meeting customer expectations (Gunby et al., 2013). If the three projects are compared, CS2 is the project with the lowest value loss in both the process and product. This result may be expected because the project in CS2 is customized as a single-family design-to-order home; the other two cases feature standard designs for the customer's established target. The ideal and real presence percentages of each attribute in the three projects are shown in Annexes 3-1 and 3-2.

In summary, the customers who received the highest desired value (or the lowest desired loss of value) were the end users and the owners, both in the process and product. This result may be because end users are dependent stakeholders who have a legitimate relationship with the project, and their requirements demand immediate attention. Furthermore, owners are definitive stakeholders; they wield the most power in the project, as suggested by Drevland & Tillmann (2018). On the other hand, the builders obtained the most significant value loss in the process, which may be because they do not participate in the design process or decision-making. In the product, the customers who received the least value are the designers; this result may be due to the high expectations unfulfilled by the type of project or due to decisions made that may meet other customers' needs but that do not meet the designers' own needs. These results could indicate that the objectives of traditional projects are not necessarily linked to the value of each stakeholder (AIA, 2007).

### 3.5.2 Types of value loss

Table 3-7 shows the relationship between the default VL, both desired and potential, concerning VL performance. It can be observed, at a general level, that the default VL is lower than those of performance; this means that most VLs are not a consequence of disagreements or conflicting positions among customers. It is possible to find higher default losses in the process than those found in the product (values between 0 and 43% versus 0 and 22%). The differences in criteria between customers may be more evident in the process because there are many actors involved, and they are all directly affected. Even though there may be differences in the product, the tendency is to satisfy the owner or end user.

Table 3-7. Types of value loss for customers

| | | | **Process** | | | | **Product** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Ow | De | Bu | Us | Ow | De | Bu | Us |
| **CS1** | Def | DVL | 14% | 0% | 0% | n/c | 0% | 0% | 0% | n/c |
| | | PVL | 12% | 0% | 0% | n/c | 0% | 0% | 0% | n/c |
| | Perf | DVL | 86% | 100% | 100% | n/c | 100% | 100% | 100% | n/c |
| | | PVL | 88% | 100% | 100% | n/c | 100% | 100% | 100% | n/c |
| **CS2** | Def | DVL | 0% | 43% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | PVL | 0% | 29% | 6% | 0% | 0% | 0% | 22% | 0% |
| | Perf | DVL | 100% | 57% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | PVL | 100% | 71% | 94% | 100% | 100% | 100% | 78% | 100% |
| **CS3** | Def | DVL | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | PVL | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | Perf | DVL | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | PVL | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **Ow: Owner; De: Designer; Bu: Builder; Us: User; Def: Default; Perf: Performance;** n/c: not consulted | | | | | | | | | | |

In CS1, the default VL is only present in the process, affecting the owner at a low level (from 12% to 14%). In CS2, the default VL is low for builders (6% in the process and 22% in the product); however, for designers, the default VL in the process is between 29% and 43%. In CS2, these results are related to a lack of integration and inadequate conflict management. CS3 did not present losses due to disagreements. No default VL affecting the end user was observed in any of the cases. These findings may indicate that customers similarly perceive the value interests of projects, as indicated by (Gunby et al., 2013).

### 3.5.3 Prioritization by customer

Table 3-8 shows the priority given to the attributes based on the MORAI criteria and the actual percentage of each attribute. Based on M>O/R>A>I, prioritization was done with all customers' responses. It is expected that this MORAI order could be used to meet the ideal percentages of each attribute: M and O: 100%; R and I: 0%; and A: optional between 0 and 100%. It can be observed in the process that the percentages of compliance with the M and O attributes are low (between 53% and 66%). In addition, the priority order does not seem to be clear; in CS1 and CS2, percentages higher than 50% of attractive attributes are fulfilled without having met the M and O attributes. On the other hand, it is observed in CS2 that R attributes could not be avoided, being present at the 14% level. No indifferent attributes are perceived in the prioritization, meaning that the attributes to which some clients were indifferent were classified differently by other clients.

Table 3-8. Priorities for customers

| | Process | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CS1 | | | | | CS2 | | | | | | CS3 | | | | | |
| | Ow | De | Bu | Priority | | Ow | De | Bu | Us | Priority | | Ow | De | Bu | Us | Priority | |
| | Qty | | | | Real% | Qty | | | | | Real% | Qty | | | | | Real% |
| M | 18 | 13 | 14 | 24 | 54% | 3 | 5 | 8 | 3 | 11 | 61% | 15 | 15 | 13 | 1 | 28 | 59% |
| O | 7 | 6 | 4 | 2 | 66% | 3 | 6 | 12 | 3 | 11 | 54% | 19 | 23 | 24 | 3 | 15 | 53% |
| R | 1 | 0 | 0 | 0 | 0% | 2 | 2 | 2 | 2 | 3 | 14% | 0 | 0 | 0 | 0 | 0 | 0% |
| A | 4 | 6 | 6 | 4 | 62% | 5 | 16 | 7 | 5 | 5 | 52% | 11 | 7 | 8 | 0 | 3 | 17% |
| I | 0 | 5 | 6 | 0 | 0% | 17 | 1 | 1 | 17 | 0 | 0% | 1 | 1 | 1 | 42 | 0 | 0% |
| | Product | | | | | | | | | | | | | | | | |
| | CS1 | | | | | CS2 | | | | | | CS3 | | | | | |
| | Ow | De | Bu | Priority | | Ow | De | Bu | Us | Priority | | Ow | De | Bu | Us | Priority | |
| | Qty | | | | Real% | Qty | | | | | Real% | Qty | | | | | Real% |
| M | 0 | 5 | 5 | 10 | 56% | 18 | 12 | 11 | 18 | 24 | 90% | 20 | 23 | 11 | 11 | 31 | 72% |
| O | 20 | 5 | 6 | 12 | 56% | 6 | 7 | 4 | 6 | 4 | 79% | 14 | 7 | 9 | 24 | 12 | 67% |
| R | 0 | 0 | 0 | 0 | 0% | 2 | 1 | 0 | 2 | 2 | 0% | 0 | 0 | 0 | 0 | 0 | 0% |
| A | 4 | 9 | 4 | 2 | 68% | 1 | 6 | 7 | 1 | 2 | 58% | 9 | 14 | 4 | 7 | 5 | 19% |
| I | 0 | 5 | 9 | 0 | 0% | 6 | 7 | 11 | 6 | 1 | 50% | 5 | 4 | 24 | 6 | 0 | 0% |

The fulfillment percentages of attributes in the product are higher than in the process, but they do not meet the ideal percentages of each attribute. The order of priorities is better in CS2 and CS3. The rate of attractive attributes fulfilled is much lower than those of M and O. The designers avoided R attributes in all cases. Regarding the indifferent ones, only one is observed in CS2, with 50% compliance, which could be inferred to be a waste of effort and resources. The indifferent attribute for all customers is "use of materials available in the market" because materials can be requested in other nonlocal markets or, due to the socioeconomic level of CS2, a request can be made for their elaboration; but, ultimately, their presence is inevitable.

### 3.5.4 Value analysis by conditions of satisfaction

Figure 3-5 shows the value losses for the satisfaction conditions of the product and process. The value losses represent the distance between the desired (and potential) value and the value generated, or the gap between what is expected and what is achieved (the lower, the better). The minimum VL is 0 (the desirable), and the maximum possible VL is 2, considering a DVI:1 and achieving a DVG: -1 (worst possible value).

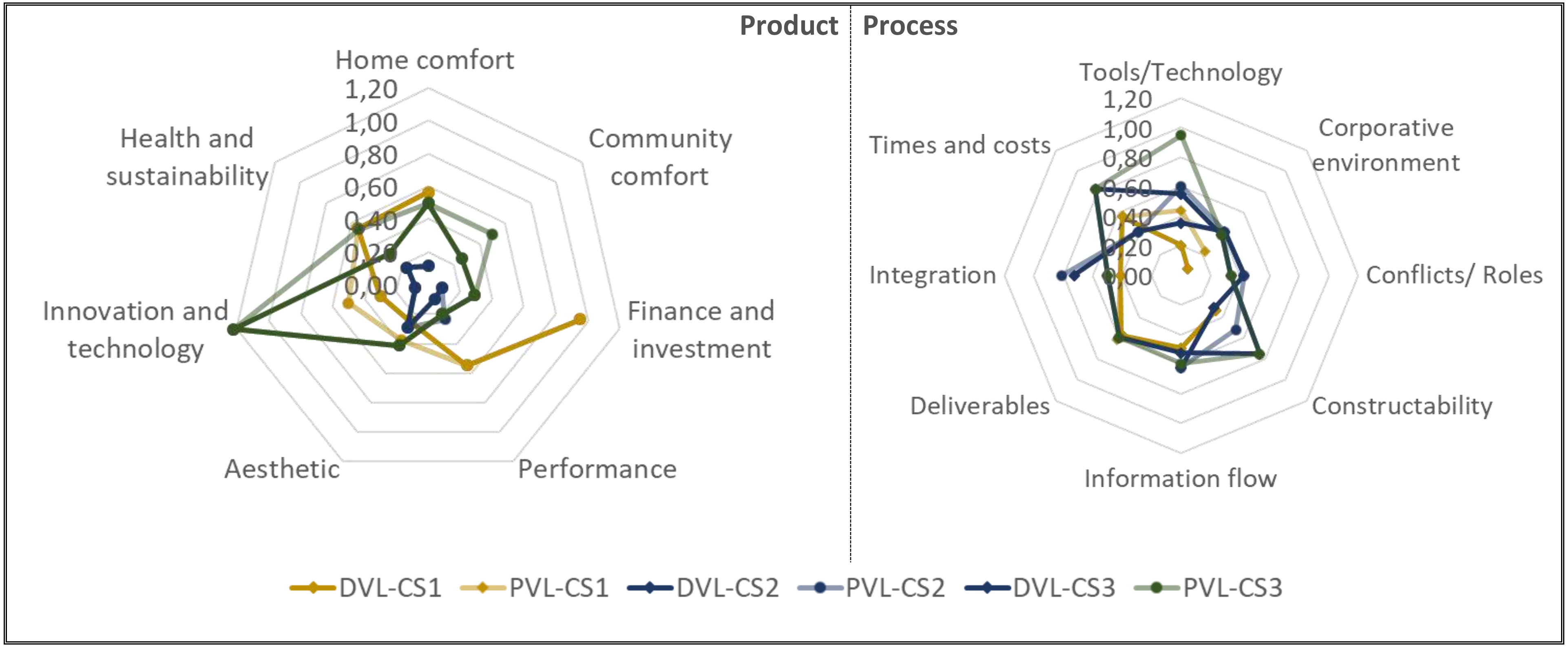



Figure 3-5. Value losses by the conditions of satisfaction

Value losses of less than 0.60 are observed in the product (between 0.25 and 0.56 in CS1; 0.08 and 0.29 in CS2; and between 0.20 and 0.50 in CS3). However, there are two outliers: innovation and technology in CS3 (1.22) and finance and investment in CS1 (0.95). These two satisfaction conditions also have the lowest value losses present in CS2 (0.08). The outlier in CS3 shows a significant value loss in primary technology attributes (telecommunications) and advanced technology such as home automation. The low presence of these attributes may be a function of the country's situation, in which there are data bandwidth restrictions and problems with the provision of essential electricity services. This project does not consider these attributes to be A but as M or O, as it aims at an upper-middle-income target. For this reason, their absence is highlighted in a case of high DVL. In CS2, the opposite is true, since the project was able to incorporate state-of-the-art technology, as required. This condition of satisfaction "Finance and investment" include location, competitive design and cost-benefit attributes. Such value losses can be associated with the socioeconomic level at which each project is targeted.

The intermediate value losses (between 0.50 and 0.56) are associated with home comfort, performance, and health and sustainability. Concerning home comfort, the multifamily housing cases (CS1 and CS3) have very similar behavior (0.56 in CS1 and 0.50 in CS3), and the value losses are related to aspects of functionality and to the length of the spaces. On the other hand, CS1 performance value losses are related to the possibilities of postsales claims, aspects related to materials, standardization, regulations and end user requirements, which are not met as expected. Regarding health and sustainability, the most significant value losses are related to the perception of not improving the end-user's quality of life as expected, difficulties with the final disposal of waste, and the maintenance of green areas.

Value losses of less than 1.00 are observed in the process (between 0.06 and 0.61 in CS1; 0.31 and 0.81 in CS2; and between 0.34 and 0.95 in CS3). The greatest value losses are observed in tools and technology (PVL), time and cost, and integration. There are considerable variability and differences between the desired and potential value losses in tools and technologies since, in this category, many attributes are considered A. Potential value losses mean that A attributes are not fulfilled, but this should not be considered a concern since the fulfillment of these attributes is optional. In this category, in CS3, the lowest PVL can be seen. The attributes related to this condition of satisfaction are the use of BIM and technological capacity. In terms of time and costs, the most significant value losses are presented by CS3 (double the losses of CS2) and are related to delays in design project delivery and difficulties in relating costs to design changes. Regarding integration conditions, the greatest value losses are presented by CS2; this result makes sense since there are separate design and construction companies that have never worked together before; they do not share risks or rewards of any kind, and they do not present joint or collaborative planning. CS1 and CS3 have very similar behavior (0.41 and 0.50, respectively) because in both cases, the design and construction companies are related by being part of the same group of companies. The lowest value loss in the process is observed in CS1 within the corporate environment, as a result of good communication and low staff turnover.

Figure 3-5 shows that the product graph clearly differentiates the 3 cases, and in the process, they tend to be confused or related. This situation may be because the design products each have their own characteristics; even though they are all housing products, they differ. On the other hand, the design-build process itself is typical in all three cases, with very similar characteristics. In this aspect, it is possible to visualize the greater emphasis on achieving the desired attributes of the product over the attributes of the process. The product, while diverse and unique, must satisfy the needs of the owner or end-user. In contrast, the process must fulfill the needs of internal customers (designers and builders) who perceive less value.

## 3.6 CONCLUSIONS

This research applied a novel model (VAM) to understand the generation and loss of value in the traditional design process, providing evidence of how this process responds to customer needs based on the different conditions of satisfaction of both the product and the process. The model was applied to three private housing projects in different phases of the design process to determine and quantify value expectations, which were then compared with the generated value, permitting the early identification of the most common value losses within the design and their probable causes related to conflicts between the value perceptions of stakeholders or the performance of the project itself.

The value expected by different customers is not provided by either the process or the product. However, the product shows less value loss than the process. The process presents negative value generation in all three cases, reflecting very high value losses. These results may be due to the characteristics of the traditional design process present in the projects, such as fragmented work teams, the lack of integration and collaboration, analog and two-dimensional information, and a high focus on costs.

In general, the customer who obtains the least value in the process is the builders, while in the product, it is the designers. On the other hand, the end users obtain the most value in both the process and the product (mainly). Builders receive little value due to their low involvement in the design process, as they are traditionally incorporated in the construction-related stages. The low perception of value that designers have regarding the product may be due to high expectations not met by the type of project or due to decisions made that meet the needs of other customers but not the needs of the designers.

Regarding the conditions of satisfaction, each case study has a prioritization order based on its unique characteristics and its environment. Some patterns in the differences or similarities among the case studies can be observed. There are more significant value losses and greater variability in product aspects related to innovation and technology and finances and investment. With regard to the process, time and costs, tools and technology, and integration are the conditions with the greatest value loss.

The value losses resulting from the different customer visions (default value losses) are low and are present in the process rather than in the product. Therefore, the main value losses are related to the performance of the project itself and not due to conflicts of perspectives between different customers.

### 3.6.1 Research contributions

One contribution of this paper is that it demonstrates that the use of VAM facilitates understanding value generation and losses in the building design process, measures how this process responds to the needs of diverse clients through different conditions of satisfaction, and evaluates the proportion of value losses resulting from differences in the interests of clients compared to those related to project performance. These value losses identified in the design stage can be anticipated and corrected in time, optimizing the value-generation process in design, reducing value losses, and maximizing value. On the other hand, the transfer of these value losses from the design stage to the construction stage can also be avoided, along with the related productivity, time, and cost consequences that this avoidance would represent.

The VAM contributes to quantifying value expectations by calculating the initial value indexes considered targets to visualize what is expected by different clients over time. Similarly, the value generated is quantified based on client perceptions and the value losses resulting from the difference between the initial indexes and the GVIs.

This research provides evidence of the greater emphasis placed on the final result (the product) than on the process. The model illustrates in detail the attributes and satisfaction conditions in which there is more significant value loss, making it possible to plan actions and make decisions to improve the process in an informed manner.

### 3.6.2 Limitations and future research

This paper was based on the experience of three case studies. Therefore, the results should not be interpreted as universal to all types of traditional building projects. Because the VAM was developed based on housing projects, the contributions of this study are also limited to this domain. We plan to extend this study to other types of AEC industry projects by applying the VAM to analyze behavioral patterns based on their similarities and differences.

The possibility of continuously measuring value will be addressed in a future paper, which will incorporate different steps in the design process and the construction process. In terms of the resources used in the design process, there is an opportunity to incorporate cost reallocation from less desirable attributes to more desirable attributes and to adjust action plans for value- and cost-oriented decision-making simultaneously.

# 4. EXPLORING VALUE GENERATION IN TARGET VALUE DESIGN APPLYING A VALUE ANALYSIS MODEL

## 4.1 INTRODUCTION

Target value design (TVD) is the application of target costing (TC-ing) to project delivery in the architecture, engineering, and construction (AEC) industry (P2SL, 2020). TVD starts at the project definition phase and financing, and then focuses on the target design process, i.e., what the client wants to achieve, its purposes and the conditions that must be met for that value to be realized (Ballard, 2012b). TVD is a management approach that aims to maximize value by iterating the design within a pre-established cost target (Rybkowski, 2009). TVD applies methods for the design to be developed considering constraints according to the customers/stakeholders' vision to deliver the required target value, within a collaborative approach. (Miron et al., 2015).

TVD differs radically from the traditional way of designing. First, TVD is a method that makes customer constraints (cost, time, location, and others) the drivers of design in pursuit of value delivery (Ballard, 2011). Second, TVD has a different way of setting prices and costs: a target cost (TC) is defined based on an established price and the profit margin (Rybkowski, 2009). Finally, TVD turns the current design practice upside-down because the designers have to (1) design based on a detailed estimate; (2) design for what is constructible; (3) work together to define the issues and produce decisions, then design to those decisions; (4) carry solution sets far into the design process; and (5) work in pairs or a larger group face-to-face (Macomber et al., 2007).

The TVD approach enables a project environment with favorable characteristics for generating value, including an emphasis on design activities, making the customer an essential participant in the process, and enhancing the customer-supplier relationship, requiring collaborative approaches (Ballard, 2011; Nanda et al., 2017). However, the primary measurement performed in TVD is not focused on value, but target cost, and some authors argue that there is an emphasis on cost over value (Miron et al., 2015; Pennanen et al., 2010).

In TVD, a systematic cost reduction exists, identifying concrete actions, incentives and continuously estimating the proposed changes to achieve the target cost. Likewise, it seeks to maintain the value requested by the client, controlling the project's scope or primary objective (Lee et al., 2012) or some measurable conditions such as metrics, capacities, among others (Pennanen et al., 2010; Zimina et al., 2012). However, there is no evidence of measurement of subjective satisfaction conditions or systematic reduction of value losses to achieve the target value.

Furthermore, documented TVD projects generally highlight the cost or schedule savings achieved (Ballard, 2012b; Zimina et al., 2012); the other requirements, benefits, and value objectives are not visibly measured or documented or are limitedly described (Miron et al., 2015). This situation may be due to the lack (so far) of accurate and rigorous value estimation methods (Ballard, 2012b). These methods should focus on capture, flow, and traceability of customer requirements throughout the project (Miron et al., 2015), and use metrics and indicators to measure value (Giménez et al., 2020).

Considering this knowledge gap, this research explores the generation and losses of value within a TVD project applying the recently developed Value Analysis Model (VAM) (Giménez et al., 2020). For this purpose, the action research (AR) approach has been used, implementing the TVD within a pilot project in a housing development and construction company to fulfill research interests and to solve the company's practical problems. The problem-solving interest is related to constant cost overruns in projects that do not obtain the desired margin or profit. The research interest is related to studying the trade-off between cost and value fulfillment in a TVD project.

This study addresses the following research question: How is target value fulfillment in the TVD project environment? The authors explore this research question by answering the following three operational questions: (1) How is the value of customer satisfaction conditions measured in the process and product of a TVD project? (2) How can value losses be identified and quantified within the design process? and (3) How is target value fulfillment compared to TC fulfillment in the TVD project environment? In this way, this research will contribute to (1) provide evidence of the measurement of satisfaction conditions, (2) identify the value losses within the design product and process, and (3) make comparisons between the fulfillment (or not) of the value expected by the customers and the fulfillment (or not) of the target cost, in order to observe if there is an emphasis on cost over value.

## 4.2 BACKGROUND

### 4.2.1 Generation and Loss of Value

Several authors define value as the relationship between the satisfaction of needs and the use of required resources (Kelly et al., 2014; Novak, 2012). In the literature, it is common to find terms like adding, aggregating, maximizing, or generating value. They refer mainly to the balance between the number of needs satisfied with the resources used for it (Zhang et al., 2016). Value can be enhanced by increasing the satisfaction of needs, even if the used resources increase, as long as the needs are satisfied more than the increased use of resources (AFNOR, 2000).

The process of generating value has been discussed from many points of view, and many methods associated with value define, analyze, and maximize it in different ways. In general, value generation is related to minimization of life cycle cost (Rischmoller et al., 2006; Tauriainen et al., 2016) and pursuit of the satisfaction of customers' needs (Gunby et al., 2013; Haddadi et al., 2016; Volkova & Jākobsone, 2016). The satisfaction of needs is achieved through consideration of the following factors: (1) requirements capture (Huang, 2017; Kowaltowski & Granja, 2011), (2) requirements flow (Bolar et al., 2017; Díaz, 2017), (3) verification that the requirements are met (Ballard & Rybkowski, 2009; Nanda et al., 2017; Zimina et al., 2012) and (4) value measurement through metrics (Giménez et al., 2020; Lin & Shen, 2007).

According to Koskela (2020), value generation is a process where customer value is created through meeting customer requirements and eliminating value losses. This concept is a way of measuring value in relative terms, the value achieved in relation to the best possible value or the portion of value not provided, even if it is potentially possible.

### 4.2.2 Target Value Design (TVD)

TVD is a management approach that aims to maximize value by iterating design within a pre-set cost objective (Miron et al., 2015; Rybkowski, 2009). It is an adaptation of Toyota's TC-ing to delivering projects in the AEC industry (P2SL, 2020). After a failed implementation attempt (Nicolini et al., 2000), it was first successfully applied in this industry in 2002 (Ballard & Reiser, 2004), which could be considered the explicit practice representing Lean thinking in design (Novak, 2012).

TVD is used to structure and manage construction projects' definition and design phases to deliver clients value within their satisfaction conditions (Tommelein & Ballard, 2016). These satisfaction conditions are typically cost and time. However, it may include other conditions of value (Ballard, 2012b) such as quality, sustainability, durability, aesthetics/appearance, operation and maintenance requirements, safety and environmental aspects; as well as potential benefits, such as problem and claims management agreements or conflict resolution (Palaneeswaran et al., 2004; Tommelein & Ballard, 2016).

TVD has a different way of pricing and costing. Traditionally, the price to bid is defined based on the cost and the established margin. Using TVD, the opposite is done; based on an established price and the profit margin, a target cost is defined (Rybkowski, 2009). Subsequently, the design process begins based on objectives, i.e., what the client wants and the conditions that must be met for that value to be realized (Ballard, 2012b; Tommelein & Ballard, 2016). This process is achieved by "costing" the design in such a way as to achieve the TC with iteration, improvement, and collaboration strategies (Rybkowski, 2009).

a) Target costing (TC-ing)

TC-ing is a tool for cost management and a strategic approach to new product development, aiming to reduce costs, ensuring quality, reliability, and other attributes that will add value to customers (Jacomit et al., 2008). TC-ing is a useful construction management technique that has improved project performance by evaluating construction component alternatives that meet the desired cost (Alwisy et al., 2020). One of TC-ing's fundamental principles is that it uses cost to input the project development process rather than output (Tillmann et al., 2017). Contrary to the traditional process of design and estimation, the market price is established first. Based on this, the allowable cost (AC) is determined, which is the maximum amount that the client is willing and able to spend for the asset (Alves et al., 2017). The target cost (TC) is then set and finally broken down to the component level to simplify the design task since it is easier to optimize the project by optimizing its components (Díaz, 2017).

b) TVD practices and tools

There are many practices and tools associated with TVD in the literature. Table 4-1 presents a summary of them. A tool is a structured technique or instrument that facilitates the implementation of principles, while a management practice refers to concrete actions associated with increasing productivity (Bloom & van Reenen, 2007; Herrera et al., 2021; O'Connor & Swain, 2013). Initially, Table 4-1 includes the first documented project practices used and recommended (Ballard & Reiser, 2004), and the fundamental practices listed by (Macomber et al., 2007). Finally, table 4-1 includes other authors who have made updates, additions, and recommendations of practices and tools that can be associated with the TVD, Lean Design, and Lean Management. This data was captured by reals project (not academic workshops) of literature (Alves et al., 2017; Ballard, 2011; Lee, 2012; Macomber, 2010; Oliveros et al., 2018; Silveira & Alves, 2018; Zhang et al., 2020; Zimina et al., 2012).

Table 4-1. TVD Practices, updates, and related tools.

| **Initial and Foundational Practices** (Ballard & Reiser, 2004; Macomber et al., 2007) | | **Tools related to TVD practices** | |
|---|---|---|---|
| 1 | Engage deeply with the client to establish the target-value. | 1 | Target costing |
| 2 | Lead the design effort for learning and innovation. | 2 | nD model (3D,4D…) |
| 3 | Design to a detailed estimate. | 3 | Functional analysis/ Value engineering |
| 4 | Collaboratively plan and re-plan the project | 4 | Last Planner System® |
| 5 | Concurrently design the product and the process in design sets. | 5 | Integrated product/cost model |
| 6 | Design and detail in the sequence of the customer who will use it. | 6 | Formal retrospectives |
| 7 | Work in small and diverse groups. | 7 | Plus and delta activity |
| 8 | Work in a Big Room. | 8 | Short co-design sessions and Big-room meetings |
| 9 | Conduct Retrospectives throughout the process. | 9 | Design-Build contract |
| 10 | Cross-functional teams. | | |
| 11 | Long term relationships with suppliers | | |
| 12 | Balance designer and constructor (team members) interests | | |
| 13 | Early integration of designers and builders | | |
| 14 | Early incorporation of main suppliers and contractors. | | |
| 15 | Sub targets cost by teams | | |
| 16 | Best value instead of the lowest first cost | | |
| **Other practices, additions, and updates (TVD and Lean Management)** | | **Tools related to TVD practices** | |
| (Alves et al., 2017; Ballard, 2011; Lee, 2012; Macomber, 2010; Oliveros et al., 2018; Silveira & Alves, 2018; Zhang et al., 2020; Zimina et al., 2012) | | 10 | PDCA |
| | | 11 | 5 minutes meetings |
| | | 12 | 5-Why™ |
| 17 | Intentionally build relationships on projects | 13 | Pareto Analysis |
| 18 | Optimize the whole project | 14 | Relational contract. |
| 19 | Projects are single-purpose networks of commitments. | 15 | Building Information Model (BIM), |
| 20 | Involve all key stakeholders in feasibility study. | 16 | A3 thinking |
| 21 | Design solutions are developed with cost, schedule, and constructability as design criteria. | 17 | CBA decision-making |

| | | | |
|---|---|---|---|
| 22 | All team members understand the business case and stakeholder values | 18 | Set Based Design |
| 23 | Set Targets for Values and Conditions of Satisfaction | 19 | TVD update charts |
| 24 | A cross-disciplinary "validation study" | 20 | Standardization |
| 25 | Aligned goals and share risks and rewards | 21 | One-page improvement reports |
| 26 | Rapid estimating | 22 | 3P (Production Preparation Process)/Mockups |
| 27 | Continuity of staff to retain the knowledge, | 23 | Virtual meetings |
| 28 | Capture of lessons learned | 24 | Charrette meeting |
| 29 | Lean set of tools to eliminate process waste | 25 | Visual management tools |
| 30 | "three musketeers" attitude. "All for one, one for all" thinking | 26 | Value stream mapping, |
| 31 | Monetary and non-monetary motivation | 27 | Prototyping |
| 32 | Support Continuous Tracking of Issues and Indicators | 28 | Gemba walks (site tours) |
| 33 | Promote transparent communication | 29 | Focus groups |
| 34 | Searching for and developing innovative solutions with the users | 30 | Innovation workbooks. |
| 35 | Encourages the discussion of problems and solutions | 31 | Design Thinking |
| 36 | Prioritizes continuous but durable improvements over time instead of more radical improvements. | 32 | Kaizen Event |

### 4.2.3 Value Analysis Model (VAM)

VAM is an analysis and measurement value model, recently developed by Giménez et al. (2020), based on the classification of attractive quality theory (Kano et al., 1984). This model captures the customers' or stakeholders' requirements in the design and construction processes and transforms them into two target value indexes: Desired Value Index and Potential Value Index (DVI and PVI). The desired value index consists only of the customer's expectations, whereas the potential value refers to the best possible value that can be obtained. Figure 4-1 shows a graphical overview of the VAM.

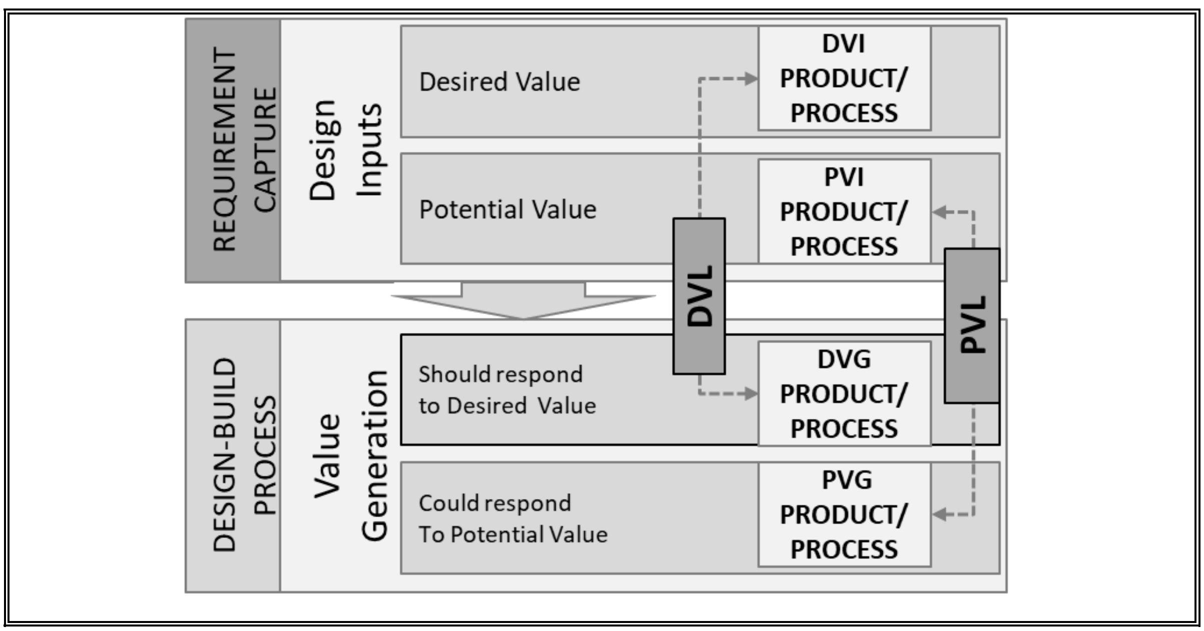



Figure 4-1. Graphical overview of the VAM. (Giménez et al., 2020).

The value generation is subsequently measured, resulting in two new indexes: desired value generated and potential value generated (DVG and PVG). Finally, a comparison is made between the target value indexes and the generated value indexes, showing numerically and graphically the value losses, which corresponds to the differences between both types of indexes. The value generated indexes must be precisely the same as the target value indexes for there to be no value losses.

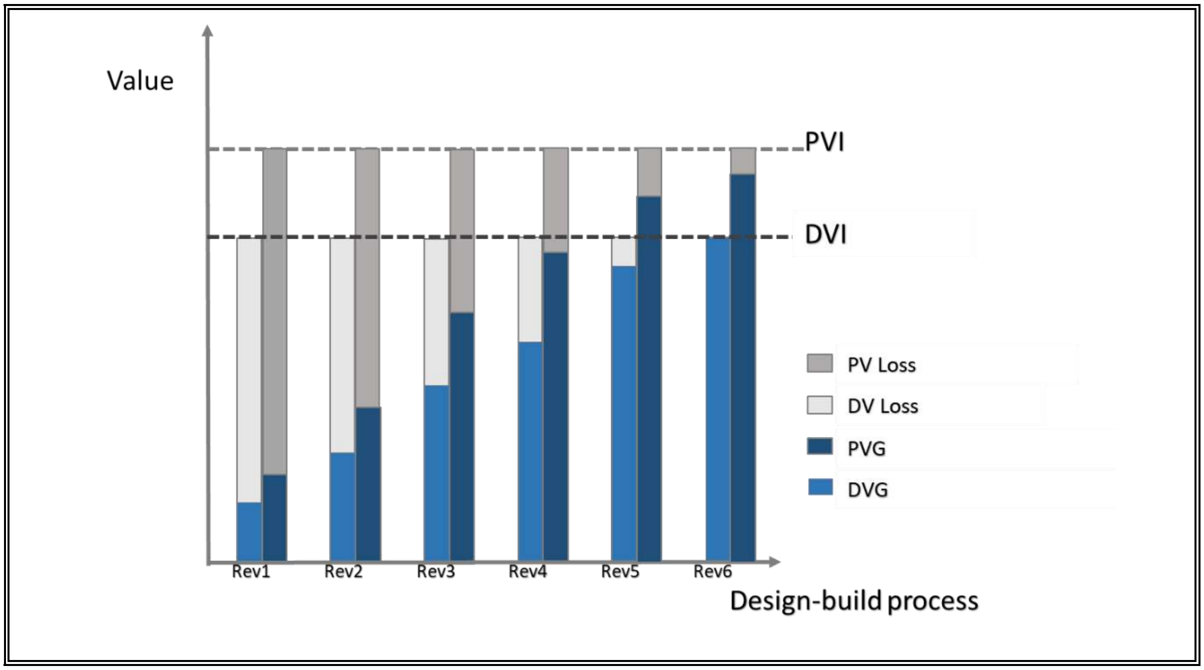



Figure 4-2. Value evolution. (Giménez et al., 2020).

The generated value indexes can be calculated throughout the design and construction processes, considering as many revisions as established by the project evaluation team. In this way, the project's value evolution can be measured both in the process and in the product in different time scenarios (Figure 4-2).

Table 4-2 presents a summary of TVD and VAM's acronyms to be used and their meaning to facilitate reading.

Table 4-2. Acronym summary

| **Acronym** | **Meaning** | **Acronym** | **Meaning** |
|---|---|---|---|
| TVD | Target Value Design | VAM | Value Analysis Model |
| IC | Initial Cost | AC | Allowable Cost |
| TC | Target Cost | TC-ing | Target Costing |
| DVI | Desired Value Index | PVI | Potential Value Index |
| DVG | Desired Value Generated | PVG | Potential Value Generated |
| DVL | Desired Value Loss | PVL | Potential Value Loss |
| DVFP | Desired Value Fulfillment Percentage | PVFP | Potential Value Fulfillment Percentage |
| W | Weighting factor | M | Must-be attributes |
| O | Onedimensional attributes | R | Reverse Attributes |
| A | Attractive Attributes | I | Indifferent attributes |

## 4.3 RESEARCH APPROACH

This research applied the Action research (AR) approach. According to Azhar et al. (2010), AR is an applied or field proactive research approach that explores real-life problems vital to the industry and fundamental research. AR aims to increase understanding of an immediate problem by performing two simultaneous actions: expanding scientific knowledge and solving practical problems. Furthermore, Mckay & Marshall (2001) conceptualize AR as two intertwined cycles: problem-solving interest and other research interests.

AR has a five-phase cyclical process studied in a research environment within a client infrastructure or system. These phases are: (1) Diagnosing, that corresponds to the identification of the primary research problem(s); (2) Action planning, that establishes the target for change and the approach to change; (3) Action taking, that implements the planned action(s) from Phase 2, where the researchers and specialists collaboratively get involved in the client organization, causing specific changes to be made; (4) Evaluating, where the results are evaluated once the actions have been completed; and (5) Learning, while the phase of learning is undertaken last, it is usually a continuous process (Azhar et al., 2010).

According to Mckay & Marshall (2001), after the initial identification of a real-world problem, a data and information gathering activity follows its nature and context, thus beginning the first cycle. Therefore, in collaboration with the participants in the process, the action researcher plans a problem-solving strategy and proceeds to implement a series of actions. These actions are monitored and evaluated in terms of their impact on the perceived problem situation. When the stakeholders are deemed to have achieved satisfactory results in the problem context, the researcher either withdraws from the situation or modifies the action plan and makes additional changes in the problem context.

In the second cycle, the researcher identifies research questions by reviewing relevant literature and designing a research project. These actions are monitored and evaluated based on the research interests and the effect the intervention has had on the research questions. If the research questions can be satisfactorily resolved, the researcher exits the organizational setting. If not, the researcher will modify the plans and designs to seek further explanations.

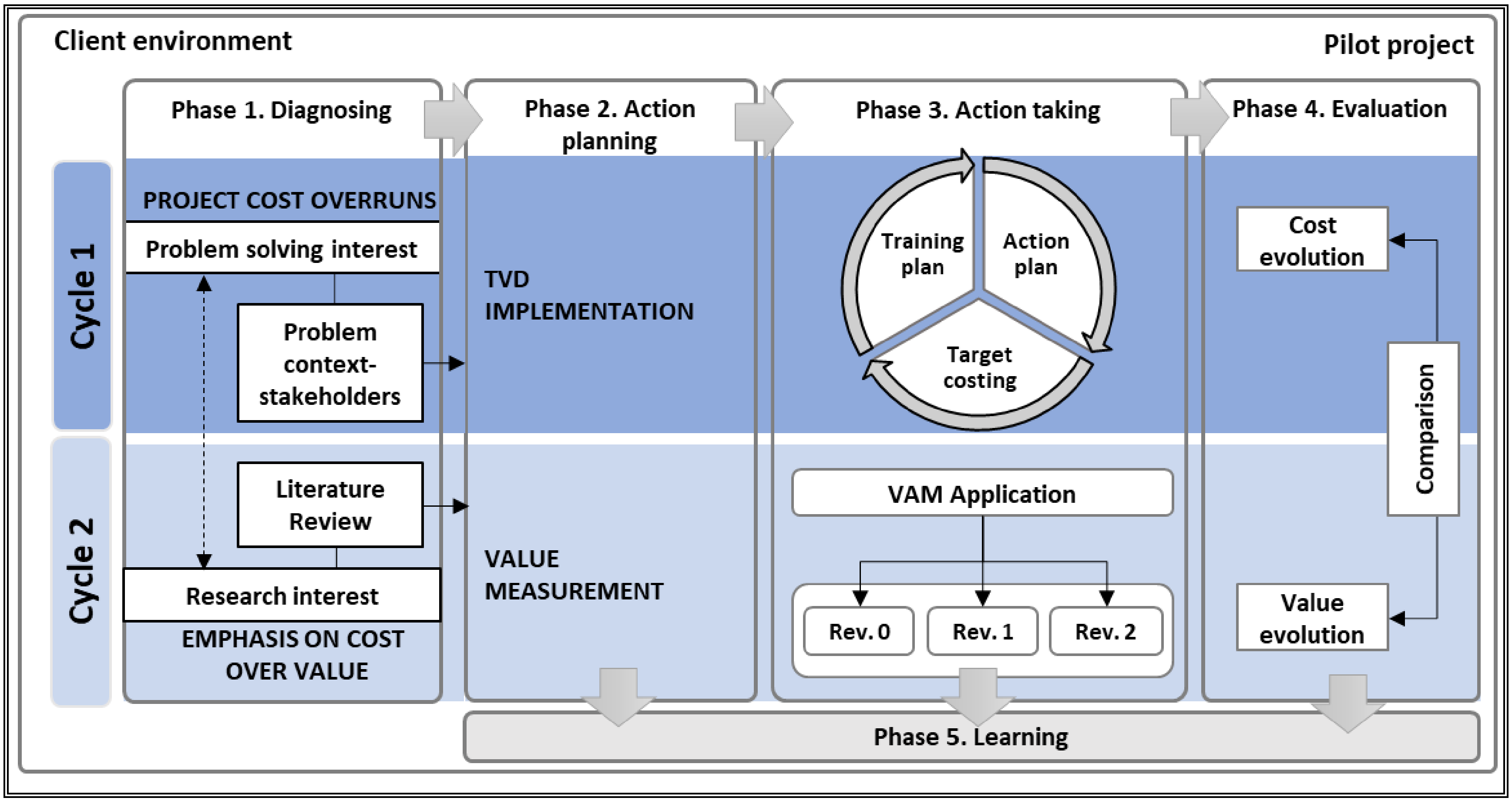



Figure 4-3. Research Approach

Figure 4-3 presents the research approach based on the five-phases process proposed by Azhar et al. (2010) related to two interconnected cycles of Mckay & Marshall (2001). The client system used in this research is a pilot project in a real estate and construction company (Company" "S"") located in Santiago de Chile, whose main activity is the integral execution of high-rise residential buildings.

In the diagnosing phase, two interests were identified: (1) constant cost overruns in the projects that do not allow to obtain the desired margin or profit (problem-solving interest) and (2) need for making comparisons between the fulfillment (or not) of the value expected by the customer and the fulfillment (or not) of the target cost, to observe if there is an emphasis on the cost over the value (research interest).

In the action planning phase, it was considered to implement TVD to incorporate a TC and to use the VAM for value measurement to address these two interests.

The action-taking phase considered how TVD was implemented, taking into account the context and characteristics of the organization and the project evaluated, and the TVD practices and tools were incorporated immediately or in the short term. TVD implementation was gradually performed (action plan), with training workshops (training plan) and constant revision of the TC (target costing). The authors also applied the recently developed VAM (Giménez et al., 2020) to measure the project's value evolution. The VAM was applied in three longitudinal reviews.

In the evaluation phase, the cost evolution was controlled through the target costing. The value measurement was realized in three longitudinal reviews to monitor the value evolution along with the project. Subsequently, the results will be compared.

The learning phase is considered a continuous process and will be captured from the action planning, action-taking, and evaluation phases.

### 4.3.1 Phase 1: Diagnosing

As explained in the methodology approach, in the diagnostic phase, the authors identified two interests, a practical one and a second one of research.

Historically, the margin achieved in the projects carried out by the company "S" has been much lower than desired. This situation responds to the high competitiveness within the real estate market, making the market price an input for the project viability and bringing constant cost deviations between the estimated and the executed. Cost overrun percentages range from 1 to 7%, which are subtracted from the already decreased profit to adapt to market prices. For this case, the TVD implementation is highly recommended since, in this design method, a TC is established to consider a target (market) price and the desired margin. Based on this target cost, concrete actions are established to reduce costs (without reducing the value) and reach the TC and, therefore, the desired margin.

Parallel to solving the practical problem described above, this study addresses a research problem related to the fulfilment of the target value in the TVD project environment. Therefore, the authors explore (1) the measurement of the value of customer satisfaction conditions, (2) the identification and quantification of value losses in the project process and product, and (3) the comparison between target value fulfilment and target cost fulfilment in the context of the TVD project.

The primary measurement performed in the TVD refers to the TC fulfillment; there is no evidence of measurement of satisfaction conditions or systematic reduction of value losses to achieve the target value. For that reason, several authors argue that the TVD focuses on cost over value (Miron et al., 2015; Pennanen et al., 2010). Based on these insights, Table 4-3 summarizes the benefits of cost, schedule, and value characteristics in real projects of the AEC industry where TVD has been implemented and whether these have been measured (explicit benefit) or not measured (implicit benefit). It can be seen that there is extensive evidence of cost as an explicit benefit and little evidence of schedule benefits; most of it is explicit.

Table 4-3. Explicit and implicit benefits on TVD projects.

| Focus or benefits | Measured (explicit) | Not measured (implicit) |
|---|---|---|
| **Cost** | (Ballard & Reiser, 2004); (Robert & Granja, 2006); (Ballard & Rybkowski, 2009); (Forbes & Ahmed, 2011); (Ballard, 2012b); (Lee, 2012); (Rybkowski et al., 2012) (Zimina et al., 2012); (Denerolle, 2013); (Nanda et al., 2014); (Do et al., 2014); (Russell-Smith & Lepech, 2015) (de Melo et al., 2016); (Alwisy et al., 2018); (Alwisy et al., 2020); (Elghaish et al., 2020); | (Nicolini et al., 2000); (Pennanen et al., 2010); (Silveira & Alves, 2018) |
| **Schedule** | (Ballard & Reiser, 2004); (Ballard, 2012b); (Nanda et al., 2014); (Russell-Smith & Lepech, 2015) | (Denerolle, 2013); (Silveira & Alves, 2018) |
| **Value** | Importance degree of value items(Robert & Granja, 2006); Reduction of design document drafting time(Forbes & Ahmed, 2011); Energy savings (Lee, 2012); 30% space reduction (Zimina et al., 2012); Safety, quality metrics (Nanda et al., 2014); sustainable target values (STV) (Russell-Smith & Lepech, 2015); value perceived by different groups of stakeholders-1 to 5 scale (Nanda et al., 2017); Value ranking analysis of key construction factors (Alwisy et al., 2018, 2020) | Functionality, durability/maintainability, and buildability requirements(Nicolini et al., 2000); relocate the building from its initial location, quality of the facility produced (Ballard & Reiser, 2004); design innovations, increased efficiency (Ballard & Rybkowski, 2009); quality (Pennanen et al., 2010); maximum long- term value for the customer, appropriate acoustic and lighting, flexibility, privacy for families and staff interaction (Rybkowski et al., 2012) quality, performance (Denerolle, 2013); benefits perceived, aesthetics, lighting, larger helipad…(Nanda et al., 2014); significant value for the project (Pöyhönen et al., 2017) performance, sustainability, value (Silveira & Alves, 2018); improvements in the design-build process (Laurent & Leicht, 2019). |

Concerning value benefits, there is documentation of implicit and explicit benefits. The explicit value benefits are observed in specific satisfaction conditions such as space reduction, reduction of design drafting times, energy savings, or metrics related to particular aspects such as safety, quality, sustainability, and constructive factors. Concerning more generalized value attributes (including several types of satisfaction conditions), two measures were evidenced: the degree of importance of value attributes based on percentages of 4 possible answers (very low, low, high, and very high importance) (Robert & Granja, 2006) and the value perceived by stakeholder groups on a Likert scale (from 1 to 5) (Nanda et al., 2017).

The implicit benefits are described in terms of improved functionality, quality, performance, and buildability requirements. An effort is observed to show that there are perceived benefits of value but with measurement limitations in the TVD projects.

### 4.3.2 Phase 2: Action planning

The action planning comprises two areas: the TVD implementation and measurement value. The author designed the action planning to be implemented in Phase 3 in three stages: pre-implementation, implementation, and post-implementation. In this phase, the authors also selected the pilot project and the people who participated in the process, designed the data collection instruments, and defined the type of information to collect.

This paper analysed a housing design project in Chile to evaluate both cost and value evolution in the design and construction process. This project was selected due to its characteristics of scope, user profiles, and level of design progress, in addition to the researcher's access to the involved stakeholders. The researchers selected a pilot project in the preliminary design stage from the company's portfolio of housing projects to enable a more effective TVD implementation. The project consists of 2 residential buildings of 11 floors each for a total of 235 housing units, a supermarket, and a shopping center, to cover the needs of the lower-middle-income socio-economic level. At the time the intervention started, the project was in the preliminary design stage. On the other hand, the organization was open to implementing the 'TDV's changes in their projects. This building was considered a pilot project according to the results obtained from it.

The authors planned with the company that the people to participate in this process would be twenty professionals from the different technical areas of the company, who represented three clients (the owner, the designers and the builders). The owner was the real estate company that requests the project's design and construction; it was represented by a director who is part of its management. The designers were represented by architecture and engineering professionals. The builders consisted of the project manager and cost staff. The progress of the project (preliminary design) did not make it possible to incorporate end-users.

Data collection was planned through interviews, work meetings, and surveys. Table 4-4 presents data collected for both cost and value evolution. Before the TVD implementation, information on the cost evolution were collected regarding the IC, AC, and TC. As the TVD practices and tools were implemented (see annex 4-3), the clusters' actions to achieve the TC were documented and estimated. The TC achievement, the implementing challenges of the TVD practices and tools both in the company and the project, and what was learned based on plus/delta activities were documented in the post-implementation program.

Table 4-4. Data Collection for stages

| | **TVD-Cost evolution** | **VAM-Value evolution** |
|---|---|---|
| **TVD Pre-implementation** | IC<br>AC and TC. | Conditions of satisfaction and Value attributes<br>DVI-PVI<br>Rev. 0: $DVG_0$ y $PVG_0$<br>$DVFP_0$ and $PVFP_0$<br>$DVL_0$ and $PVL_0$ |
| **TVD implementation** | Actions to be incorporated to achieve TC<br>Continuous cost estimates.<br>Learning plus/delta | Rev 1: $DVG_1$ and $PVG_1$<br>$DVFP_1$ and $PVFP_1$<br>$DVL_1$ and $PVL_1$ |
| **TVD Post-implementation** | Achievement of TC.<br>Challenging to implement TVD practices and tools<br>Learning plus/delta | Rev. 2: $DVG_2$ and $PVG_2$<br>$DVFP_2$ and $PVFP_2$<br>$DVL_2$ and $PVL_2$ |

Regarding the value evolution, the researchers initially determined (before TVD implementation), satisfaction conditions, value attributes, the desired and potential value indexes (DVI and PVI). These indexes represent what was expected by the client and the highest possible value to be delivered, respectively. Three revisions (Rev) were made of the value generated (DVG and PVG), value fulfillment percentage (DVFP and PVFP), and value losses (DVL and PVL). Rev 0 represents the initial value before the TVD implementation, Rev 1 is the value while incorporating some TVD practices and tools, and Rev. 2 is the value after the TVD implementation program.

### 4.3.3 Phase 3: Action taking

The authors incorporated TVD in the company through a research alliance between industry and academia. The program was called "on the path to TVD" and was implemented by adapting it to the country's cultural context, the company, and the selected project, focusing on training-action; this means implementing the practices and tools as the professionals were trained in a period of 10 months. These professionals were from the Real Estate Management and Construction Management department of the company "S".

a) TVD Pre-implementation

The authors scheduled preliminary meetings to establish the action-training plan, determine the group of professionals who would participate, and set the project's AC and TC. Additionally, the authors collected information regarding value attributes within the conditions of product satisfaction and the design and construction process. The product's satisfaction conditions are home comfort, finance and investment, performance, image, innovation and technology, and health and sustainability. Annexes 4-1 and 4-2 show the value attributes and their relationship with the conditions of satisfaction. The process satisfaction conditions are information flow and communications, time and costs, tools and technology, constructability, integration, corporative environment, and deliverables.

The value attributes were collected in a survey within one of the preliminary meetings in which the group of participants was asked the following questions: (1) Describe different value attributes that you consider essential to the following customers: user, owner, designers, builders, and reviewers; and (2) If you had to give importance to one customer over another, what would be the order and percentage of importance to you? The answers to these questions were complemented through interviews with the owner and some professionals who could not attend preliminary meetings. Satisfaction conditions were established according to the literature review (Ballard, 2012b;

Palaneeswaran et al., 2004; Ruiz et al., 2014) and their relationship with the collected value attributes.

The authors formed four participant clusters (called committees): cross-functional teams of 4 to 8 people. The committees were divided according to systems within the project: 1. Structure and urban development, which includes the foundations, slabs on grade, superstructure, roofing, exterior walls, and urban development; 2. MEP, including HVAC, plumbing, electrical, and conveying systems; 3. Finishes; and 4. Logistics. These committees attended weekly work meetings. Also, the authors established workshops on TVD practices and tools, general meetings on action proposals with all committees' attendance, and meetings to review compliance with teams' agreements.

It was determined that three sub-management areas of real estate management and five sub-management areas of construction management would be the group of professionals participating in the program. Within real estate management were: project, architecture and engineering, and sales sub management; and within construction management were: project and construction administration, delivery and after-sales, quality, costs and procurement, and logistics sub management.

At a meeting of senior management, the AC and TC were determined. The TC was established according to the market price and the desired margin. Since the margin historically achieved in the projects carried out by the company has been much lower than the desired one, the AC was established according to the market price and the intermediate margin between the desired and the historical margin. The researchers were present at the meeting to guide the managers in determining these costs.

b) TVD Implementation

The TVD implementation comprised three sections that were conducted simultaneously: training plan, action plan, and target costing.

i) Training plan

The authors implemented training workshops based on the TVD practices and tools. The first workshop was the TVD introduction, which included basic concepts, the nine fundamental practices of (Macomber et al., 2007), and other complementary practices of other authors. Six additional workshops were planned to be delivered in two-hour sessions with approximately 20 professionals from the company. The workshops' topics were the following: constructability, choosing by advantages (CBA), A3 thinking, innovation and continuous improvement, integrated project delivery (IPD), and Building Information Modeling (BIM). The authors also introduced other concepts regarding practices and tools of TVD to complement the primary topics. For example, target customer, industrialization, the importance of advantages, nD models, Virtual Design and Construction, collaboration levels, root cause analysis, 5W+2H, relational contracts, BIM coordination, kaizen event, and design thinking. Annex 4-3 contains the practices and tools from table 4-1 incorporated through the company's action and training plan.

ii) Action plan

The authors implemented the action plan gradually through big-group meetings (similar to the big-room in the company) and cluster work through committee meetings. The practices and tools were tested and incorporated into the project, as they were learned in the workshops. Each cluster was responsible for a part of the gap between the TC and the IC proportional to its area's budget (sub-targets). Based on the Pareto analysis, the committee's budget was ordered according to the items or macro-items by costs, from highest to lowest, to establish concrete actions to achieve the target cost systematically. The researchers brainstormed to establish possible actions and their priority. The CBA decision-making method was beneficial in cluster discussions to establish which actions should be incorporated or not, and to choose the most significant advantages among various alternatives.

Likewise, the researchers established "rules" for the committee and big-group meetings, in which an atmosphere of trust, open communication, and participation should remain. The group established and analyzed from the points of view of different clients, problems to be addressed or desired situations to be reached, and they subsequently proposed actions. These actions were reviewed to see if they impacted other activities or actions of other committees. Where possible, cost/time/benefit metrics of the proposed actions were requested.

All the clusters or a representative of the cluster were present in the big group meetings. These meetings had different purposes: (1) Review of the proposed actions by cluster and if they were related to other clusters, (2) Review of the difficulties to implement TVD practices and tools both in the project and in the company, (3) Feedback meetings (plus-delta) to direct the efforts towards the best for the project, and (4) Kaizen event style meeting, to innovate and explore through design thinking and PDCA.

iii) Target costing

The estimates did not respond in time to the proposed actions because they were made centrally by the cost department, and it would be desirable to incorporate cost estimates of the proposed actions on a continuous and faster basis. Given the delays in this estimation, the cost department made visible to each committee the costs associated with all project items so that the committee itself would make the relevant estimates. This action contributed significantly to accelerate the cost estimates.

The authors designed two types of TVD update formats based on two examples presented by Ballard & Reiser (2004). The first one recorded the date, description of the proposal, and estimated cost of proposals generated in the committee meetings. The second one corresponds to monthly follow-ups, which recorded the actions proposed by the committee, descriptions, the estimated cost, and the cost since the last change. These formats contributed to elaborate the project's cost evolution charts.

c) TVD Post-implementation

The authors analyzed the target 'cost's fulfillment after implementing the "on the road to TVD" program, as explained in the results section. Also, the authors identified difficulties and overall benefits of the implementation program through a plus/delta activity and established future actions for the company. Phase 5 (learning) introduces these items.

d) Value Measurement

As explained in the TVD pre-implementation, the group identified the customers present in the process and gave them a weighting in percentage according to their importance. This ponderation is a weighting factor (W) per customer, which corresponds to the average of all the responses received. It is essential to clarify that for the value assessment, the group of professionals ruled out the reviewers, and the end-user could not be consulted due to the preliminary state of the project. Therefore, the customers identified were: owners, designers, and builders.

For the DVI and PVI calculation, the authors classified the list of value attributes according to the types proposed by Kano et al. (1984): Must-be (M), One-dimensional (O), Reverse (R), Attractive (A), and Indifferent (I), using a two-dimensional survey. The survey's first question was functional: How do you feel if the proposed attribute is provided? The second question was dysfunctional: How do you feel if the proposed attribute is not provided? Each question (either functional or dysfunctional) had five response options: Like, Must be, Neutral, Live with, and Dislike. Based on both responses, the ranking of the attributes is achieved. Subsequently, according to this classification, each of them is multiplied with a value established in the VAM (Giménez et al., 2020), which are presented in Table 4-5. To calculate the DVI, only what the client expects is considered (marked with asterisks in Table 4-5). The DVI is the sum of the products of the number of attribute types and their valuation (expected presence or absence) divided by the total attributes. On the other hand, the PVI is the sum of the DVI with the percentage of "A" attributes.

Table 4-5. Attribute valuation VAM (Giménez et al., 2020)

| Attributes | Value | |
|---|---|---|
| | Present | Absent |
| M | 0* | -1 |
| O | +1* | -1 |
| R | -1 | +1* |
| A | +1 | 0* |
| I | 0 | 0 |
| * expected by the customer | | |

Based on these calculations, the authors established the DVI and PVI of each client in the process and the product. The total DVI and PVI of the project would be the sum of the products between the indexes and W (Table 4-6).

Table 4-6. DVI and PVI by customers and total project.

| | Product | | | | Process | | | |
|---|---|---|---|---|---|---|---|---|
| | Customer | | | Total | Customer | | | Total |
| | Owner | Designers | Builders | Project | Owner | Designers | Builders | Project |
| **W** | 41.6% | 27.6% | 30.8% | **100%** | 41.6% | 27.6% | 30.8% | **100%** |
| **DVI** | 0.79 | 0.25 | 0.29 | **0.49** | 0.27 | 0.20 | 0.13 | **0.21** |
| **PVI** | 1.00 | 0.63 | 0.42 | **0.72** | 0.40 | 0.40 | 0.33 | **0.38** |

For calculating the value generated, the authors applied a survey with the list of attributes to quantify each attribute's level of presence and absence. The survey questions were worded as follows: "Regarding the list of attributes of the design process shown below, what percentage do you perceive to have been fulfilled in the project? If you are not aware of the item, please answer 'I have no information'". DVG and PVG are calculated from each attribute type (see Table 4-5) and the level of presence and absence of each one, as shown in equations 1 and 2.

$$DVG = \frac{(Ma * -1) + (Op * 1) + (Oa * -1) + (Rp * -1) + (Ra * 1)}{M + O + R + A + I} \quad (1)$$

$$PVG = \frac{(Ma * -1) + (Op * 1) + (Oa * -1) + (Rp * -1) + (Ra * 1) + (Ap * 1)}{M + O + R + A + I} \quad (2)$$

M: must-be, O: one-dimensional, R: reverse, A: attractive, I: indifferent, p: level of presence, and a: level of absence

The authors made three revisions to measure the value: Revision 0, which coincides with TVD pre-implementation; Revision 1, in TVD implementation; and Revision 2, performed after approximately six months of TVD implementation. In these revisions, the DVGs and PVGs were calculated and compared with the initially calculated DVI and PVI, resulting in value fulfillment percentages (DVFPn and PVFPn) and value losses (DVLn and PVLn). Value losses are the gap between PVI and PVG; and DVI and DVG.

### 4.3.4 Phase 4: Evaluation

a) Cost evolution

The gap between TC and IC was distributed among the four committees proportionally to the committee's participation in the total project budget. Table 4-7 illustrates this gap distribution (sub-targets) in thousands of U.S. dollars, the reduction amounts achieved (in thousands of U.S. dollars), and gap achieved percentages per committee. The results show that two committees could not achieve the corresponding sub-target (finishes and logistics), but the other two committees achieved a much higher percentage than expected (more than 200%). The project achieved the target cost and an additional 39% reduction. It is essential to highlight that the success was achieved jointly by the four committees, complementing each other's actions requested and incorporated between committees.

Table 4-7. Gap distribution among the committees

| Committee | Participation in total budget (%) | TC-IC Gap (thousands USD) | Cost reduction achieved (thousands USD) | Cost reduction achieved (% of Gap) |
|---|---|---|---|---|
| **Structure and urban development** | 28.60% | 75.6 | 165.72 | 219% |
| **Finishes** | 38.80% | 102.5 | 27.25 | 27% |
| **MEP** | 19.70% | 52.1 | 150.56 | 289% |
| **Logistics** | 13.00% | 34.3 | 25.21 | 73% |
| **Total** | 100.00% | 265.64 | 368.74 | 139% |

Figure 4-4 shows the cost evolution throughout the project. This chart was constructed based on the gap between the estimated cost and the target cost. Figure 4-4 depicts seven cost estimates, corresponding to the project committees' actions until the TC goal is reached and exceeded. From the fifth estimate onwards, the committees achieved the TC, but kept implementing actions to achieve even more savings, reaching an additional 104 thousand dollars of saved costs.

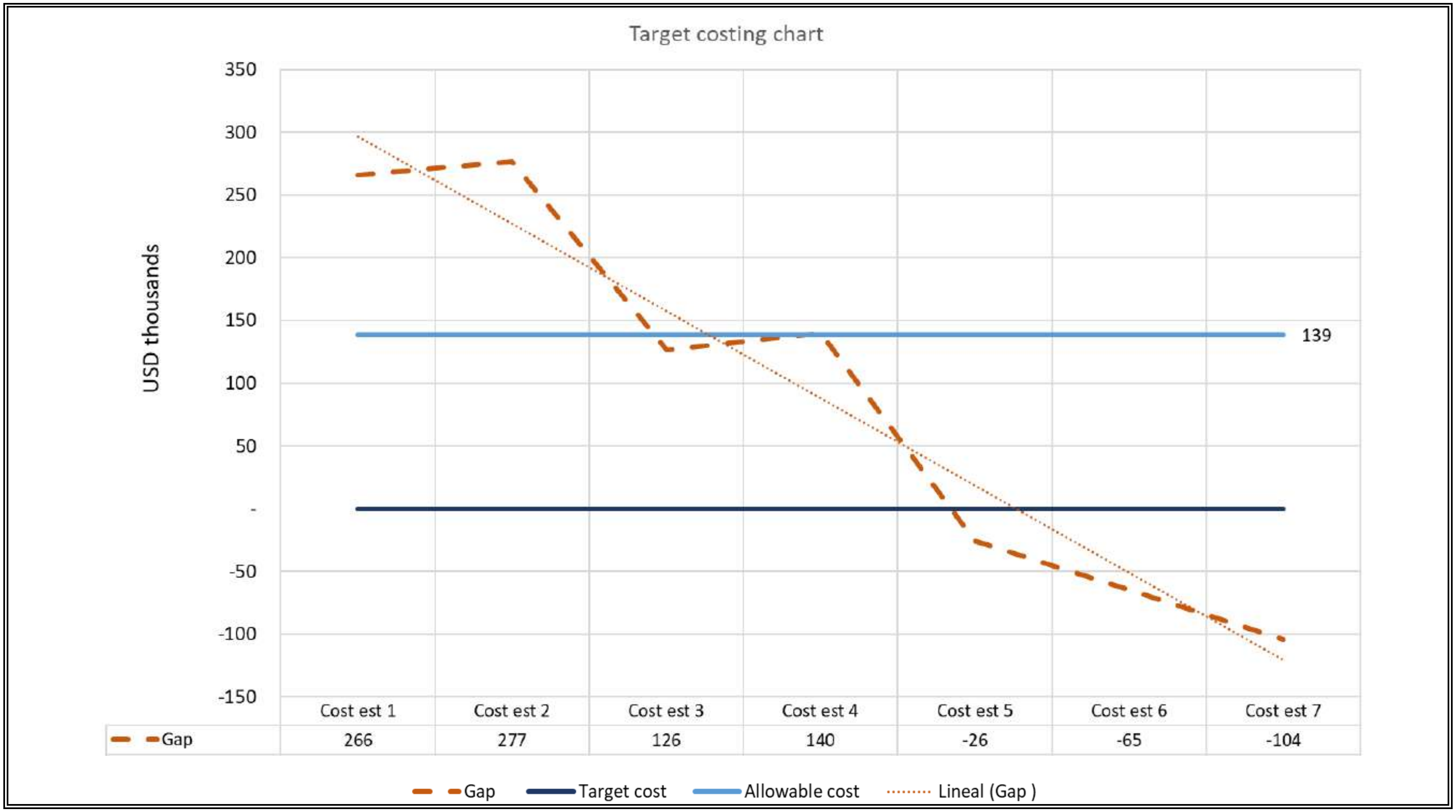
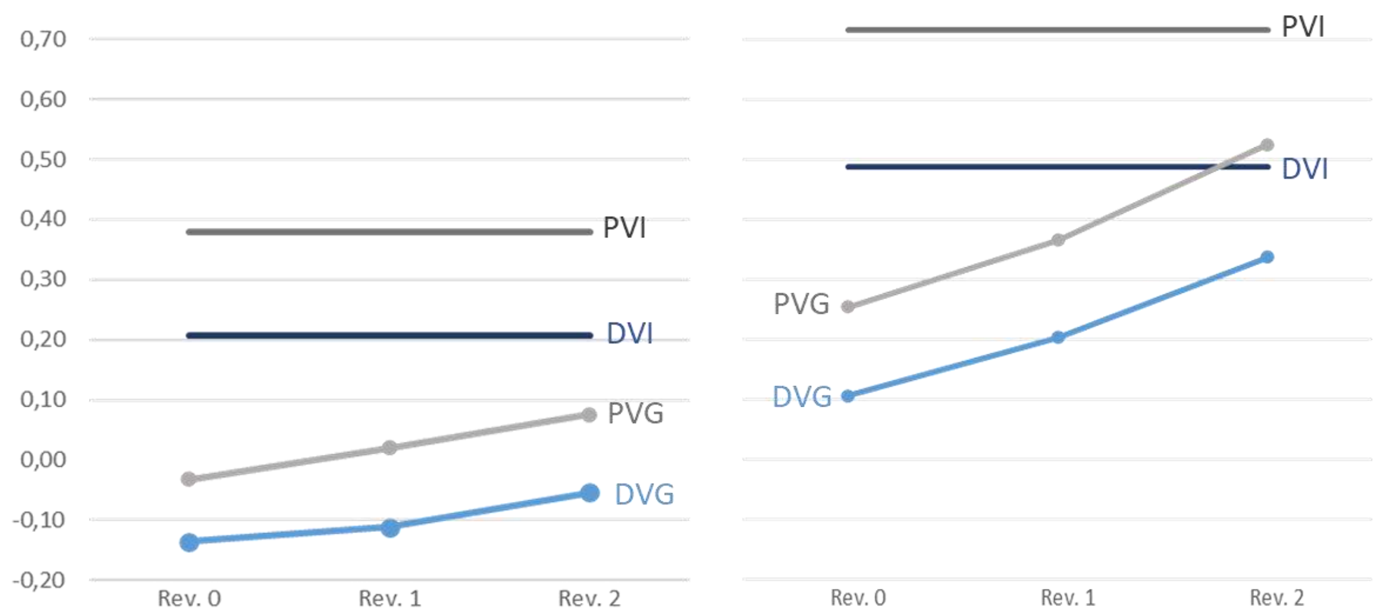



Figure 4-4. Target costing chart. Cost evolution

b) Value evolution

This subsection shows the results of three value reviews of both the process and the project's design product. Figure 4-5 shows the value evolution, where the value increases (dotted lines) and value losses (dashed and dotted line) decrease as the project progresses. However, neither case (product or process) achieved the desired or potential value. In the product, the reduction of value losses is more pronounced than in the process. This difference between product and process may be because it is generally designed thinking about the final product and not necessarily considering the process, even though one of the practices of the TVD is the integration of the product and the process, being able to use product-process-cost models (Ballard, 2011).

The value generated in the process is low, reaching negative numbers. In the VAM, negative values represent (1) the non-incorporation of essential or "M" attributes; (2) the low fulfillment of "O" attributes; (3) the incorporation of "R" or contrary attributes to what is desired by customers; or (4) the combination of all the above possibilities. Incorporating M attributes alone avoids customer dissatisfaction, bringing the value to an initial level of zero. The absence of "O" attributes or the presence of "R" attributes reduces the product or process value and can reach negative numbers.




| | Rev. 0 | Rev. 1 | Rev. 2 | Rev. 0 | Rev. 1 | Rev. 2 |
|---|---|---|---|---|---|---|
| DVI | 0,21 | 0,21 | 0,21 | 0,49 | 0,49 | 0,49 |
| PVI | 0,38 | 0,38 | 0,38 | 0,72 | 0,72 | 0,72 |
| DVG | -0,14 | -0,11 | -0,05 | 0,11 | 0,20 | 0,34 |
| PVG | -0,03 | 0,02 | 0,08 | 0,25 | 0,37 | 0,53 |
| DVFP process | -65% | -54% | -26% | 22% | 42% | 69% |
| PVFP process | -8% | 5% | 20% | 36% | 51% | 73% |

Figure 4-5. Value evolution

The last two rows show the desired and potential value fulfillment percentage in each revision (DVFP and PVFP). If the trend of adding value in the project is maintained, the product could reach DVFP and PVFP above 90%, minimizing value losses to percentages of less than 10%, these numbers being very acceptable. However, the process would still not reach tolerable values since the DVG would still have negative terms, and the PVFP could reach a percentage close to 30%.

c) Comparison between Value and Cost evolution

This subsection shows the differences between the evolution of value and costs in three reviews. Figure 4-6 presents the three revisions made in the value measurement related to the cost evolution. Rev0 of value coincides with the IC of the project, Rev1 coincides with the fifth cost estimate (see Figure 4-4), and Rev2 of value was performed about eight months after the end of the TVD implementation program and is assumed to be the same as the last cost measurement made on the project. The results show how to target cost is achieved and value increase as the project progresses. However, the fulfillment of the TC is higher than the value. In revisions 1 and 2, even though the TC was already met and exceeded, this is not the value case. Both the desired and potential values are not fully satisfied in either the process or the product. Nevertheless, the value does not decrease while the TC is achieved, but it is also feasible to increase even if costs decrease. It is imperative to highlight that by using TC-ing, systematic actions have been carried out to achieve the TC, but not the value, so this could be one reason why the DVI or PVI have not been reached.

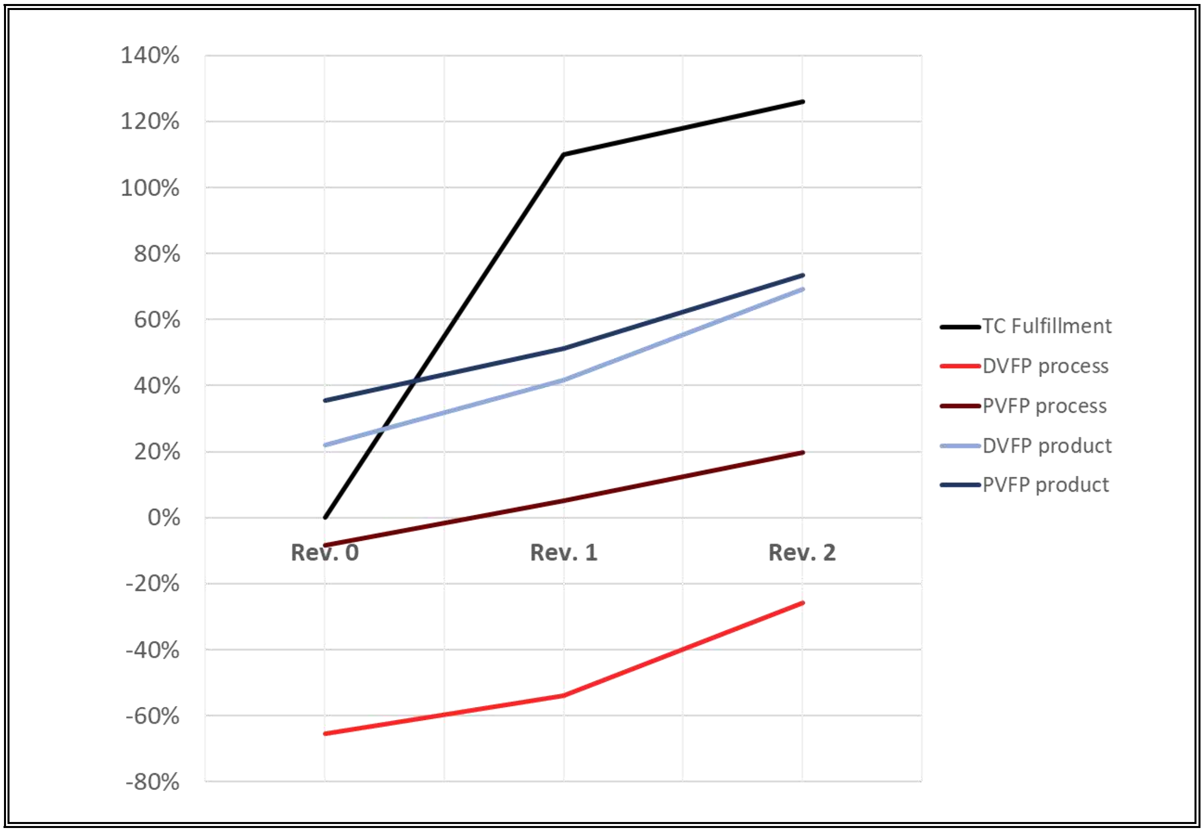



Figure 4-6. Comparison between cost and value evolution

### 4.3.5 Phase 5: Learning

To collect the learning obtained in the TVD implementation program, the authors used the plus/delta tool, where the participants expressed the positive and improvable aspects of the process. This tool was used in different intermediate sessions and at the end of the implementation. The main 'participants' opinions are the following:

The TVD was considered a useful methodology for collaborative development. The use of CBA and the creation of committees for collaborative work were very positive. Likewise, the transparency in communication and information and the better management of costs is appreciated. The cost department made visible to each committee the costs associated with all project items to make the relevant estimates. This action contributed significantly to the continually and rapidly cost estimate.

Regarding the difficulties, it was considered that there is staff turnover since it is estimated that there were 4 to 5 additional hours of work in these ten months, so planning must be improved. In addition, the committee's composition should be improved to optimize the participants' time. On the other hand, the updating costs process should be adjusted since it was not carried out correctly, especially at the beginning.

The TVD practices where the participants faced the most significant difficulties were: designing concerning the client's budget and target value, working in a big room, and collaborative planning. However, alternatives were proposed to counteract these difficulties, such as generating a data bank of $m^2$/quality of finishes and utility installations, creating a new budget model with a classification of areas, resources and current capacities, and implementing and training BIM to improve early budgeting. Regarding the big room, the following proposals emerged: big virtual room, use of Last Planner System® from the design stage, in order to decrease latency times in requests and responses, and have more efficient coordination meetings of specialties. Concerning collaborative planning, the authors propose the use of ICE (Integrated Concurrent Engineering) sessions (Fischer et al., 2017) supported by BIM, having a common objective of company "S" and not by departments or headquarters, and establishing a moderator to manage times.

## 4.4 DISCUSSION

This section elaborates on the important aspects of the results obtained. First, the emphasis on cost over value is addressed. Secondly, the reason why the desired or potential customer value is not achieved in the project is explored. Thirdly, more significant value losses are evidenced within the process than within the design product.

Within the TVD implementation process in the company, the emphasis on cost over value is perceived, already described by several authors (Miron et al., 2015; Pennanen et al., 2010). The gap between the initial cost and the target cost was systematically decreased through concrete actions required throughout the meetings and workshops. These actions were the result of reviews of budget items in order of highest to lowest cost impact. Therefore, the proposals focused on cost reduction and subsequently on other time, productivity, or value benefits.

However, even though the value was not the main reason for making decisions on whether or not to implement the actions, the professionals observed whether the proposed changes could impact the project's value. Evidence of this is the replacement of elevators with higher capacity cabins, which resulted in a reduction in their number without affecting the traffic study. This study, by regulation, must meet the vertical mobility needs of users in a given time and space. Therefore, a monetary reduction was achieved while maintaining the value for the client. This behavior coincides with what was stated by Lee et al. (2012), who affirm that TVD projects seek to preserve the value requested by the client, controlling the scope or main objective of the project.

Also pursuing some measurable conditions such as capabilities, metrics among others (Pennanen et al., 2010; Zimina et al., 2012).

It was discussed that documented TVD projects often highlight cost or time savings achieved (Ballard, 2012b; Zimina et al., 2012), value benefits are not measured or are described in a limited way (Miron et al., 2015). It was thought that this situation might be due to the lack (so far) of accurate and rigorous value estimation methods (Ballard, 2012b) that focus on customer requirements (Miron et al., 2015). This paper attempts to fill this knowledge gap by incorporating a literature review of actual TVD projects that have documented the costs, schedule, and value benefits.

The authors noted that costs are documented very explicitly. Total cost measurements, comparative costs with other non-TVD projects, Cost per square foot, project life cycle costs are shown (Ballard & Reiser, 2004; Ballard & Rybkowski, 2009; Denerolle, 2013; Zimina et al., 2012). The benefits of time have been predominantly documented, mostly by comparing times with other projects without TVD or stating that the established time was met (Ballard, 2012b; Nanda et al., 2014). Regarding value, it is observed that although there are measurements regarding specific aspects related to the project's main objective or scopes, such as energy savings (Lee, 2012) or considerable space reduction (Zimina et al., 2012), most of the benefits are shown implicitly. These aspects are related to functionality, durability, buildability (Nicolini et al., 2000), quality (Denerolle, 2013; Pennanen et al., 2010), privacy, flexibility, acoustics and lighting, aesthetics (Nanda et al., 2014; Rybkowski et al., 2012), sustainability (Silveira & Alves, 2018), design improvements and innovations (Laurent & Leicht, 2019).

However, even though meeting the target cost in the TVD projects does not decrease the value, the desired and potential value of the clients was not achieved in this project. When the target cost was reached, the committees continued working to achieve more savings, but not with the value. The committees managed actions to reduce the cost, but no actions were proposed to achieve the target value. It was possible to visualize the cost for the professionals of the project, but it was visualized very late that the value attributes were not being achieved or did not have good percentages of presence in the project. It would be interesting to jointly search for the optimization of the presence of the value attributes starting with those of the highest level of importance according to the order M>O/R>A>I.

On the other hand, although the committees did not consciously seek concrete actions to achieve the target value, as was done with the cost, the value was increasing throughout the revisions made to the project. This situation may respond to the fact that the TVD methodology incorporates practices and tools that bring benefits to the design process that had not been explicitly measured until now. According to the results, the product managed to be more functional and energy-efficient, comply 100% with the regulations, and improve the community's quality of life. Also, the design process better incorporated information technologies for the specialty coordination, improved the response time to requests for information, and cost information was shared to a greater extent with the professionals involved in the project.

According to the results, the reduction of value losses is more pronounced in the product than in the process. This difference may be because more emphasis is generally placed on the design product and not on the design process. In addition, it is to be expected that the value attributes of the product will be incorporated as the design process progresses and iterates better solutions.

TVD recommends integrating the product and the process, using product-process-cost models, referring to the fact that as the product is being designed, the way it will be executed or produced in the construction phase is also designed. The study addressed attributes related to the design process such as information and communication management, time and costs, tools and technologies, and corporate environment; the attributes of constructability, integration, and deliverables had a greater relationship or impact on the process of the construction phase. These attributes are characteristics of the way of working or the company's culture and are more difficult to modify than the product design of a project. Process-related attributes reflect each company's particular way of producing, its protocols, its barriers and obstacles to implementing changes and improvements. Also, the context, the city or country where it is located, the social, economic, cultural and political aspects influence the processes and the management of the projects. These improvements require gradual changes that cannot be achieved in the short term.

## 4.5 CONCLUSIONS

This paper aims to explore the generation and losses of value within a TVD project through metrics applying the recently developed VAM (Giménez et al., 2020). According to the results obtained, there is a tendency towards an increase in value as the project progresses; however, the desired or potential value was not achieved in the process or in the product. In comparison, the value generation is more pronounced in the product than in the process. The value generated in the process is very low (in fact, negative); this means that the most important attributes (M and O) are not met, or opposite characteristics (R) are present that decrease the value, resulting in significant value losses. In addition, it can be seen that even though the desired or potential value has not been reached, the target cost is not only achieved but exceeded.

Based on the results obtained in this study, the main theoretical contributions are (1) the possibility of measuring value in TVD projects; (2) visualization of the evolution of the value of a project, and the decrease (or increase) of value losses over time; and (3) the possibility of being able to compare cost and value. The main practical contribution is to show explicit evidence of the emphasis of cost over value and product over the process in TVD projects.

The VAM measures how value has been generated in the process and in the design product by establishing indices that measure the different conditions of satisfaction proposed and required by multiple customers. Therefore, it is possible to provide explicit information on the desired value, the maximum possible value (potential value), the value generated in the product and the process, and the value losses as the gap between what was expected and achieved. Benefits that were initially envisioned in an assumed or implicit way (not measured, only reported) (see Table 4-3) can be transformed into explicit ones (measured and traceable) through (1) the quantification of value expectations by calculating initial value indices (DVI and PVI), (2) the measurement of value generated (DVG and PVG) from customer perceptions, and (3) value losses resulting from the difference between the above indices. These measurements can allow the inclusion of value-related parameters in traditional project performance measures (time, cost, and productivity). VAM provides measurement with a common language for all value attributes.

It is also possible to visualize the evolution of the value of a project and the decrease (or increase) in value losses over time. This condition makes it possible to review whether the value is increasing or decreasing and whether this is due to the incorporation of actions, practices, or tools in the project's development. Value losses are identifiable from the design phase, allowing measures to be taken to minimize them to maximize value.

In addition, VAM measurements make it possible to compare cost and value. The model illustrates in very similar terms the target costing with the measurement and evolution of value, which makes their comparison feasible: the TC with the potential value, the AC with the desired value, which are the objectives to be achieved, and the percentage of fulfillment of target value or TC, respectively. The estimation of the cost and value generated in a review at a project milestone compared to the objectives causes measured and traceable cost gaps or value losses that the actions proposed by the work team can reduce.

This research provides evidence of the current increased emphasis on cost versus value. This knowledge may contribute to placing the focus on value attributes and balancing the cost-value relationship within projects. This research also shows that cost minimization can be achieved without detriment to the value of TVD projects.

Additionally, VAM is a helpful model that provides explicit information, which may be necessary for design-build projects involving many stakeholders or clients. VAM can help reach agreements to establish value in a project by showing the different perspectives of clients and directing them toward a similar prioritization path that seeks the best possible value.

On the other hand, VAM allows researchers to conduct systematic studies searching for the value generated by applying innovative design and construction methods, different project delivery models, or the review of value under specific project satisfaction conditions, such as sustainability and safety attributes. In summary, VAM could be considered a value estimation method that focuses on capturing, flow, and traceability of customer requirements throughout the project using metrics and indicators to measure different value conditions.

### 4.5.1 **Limitations and future research**

This paper was based on the experience of one housing project. Therefore, the results should not be interpreted as universal to all types of building projects. The contributions presented in this document are also limited to this domain.

It is essential to highlight that systematic actions have been taken to achieve the TC by using target costing. It would be interesting to use an analogous methodology with value, a "target valuing" that allows incorporating concrete actions to achieve the desired and potential value. In VAM, a gap is obtained between the expected value and the value generated, known as value loss. Knowing this gap and why it occurs, actions can be identified to minimize it and thus achieve the target value and the allowable value (potential and desired value).

# 5. CONCLUSIONS

## 5.1 SUMMARY

The fundamental research question addressed in this study is how does TVD contribute to the generation of value in design? To answer this question, this thesis addressed three operational questions.

The first question explored how to measure and analyze value generation and losses in design. The author identified a lack of methods that link the capture of customer requirements with the ongoing measurement of value generated. The development of a value analysis model was proposed to establish the level of value generated in the design concerning the value desired by customers and to identify design value losses on time. The validation of the value analysis model (VAM) and its application in a pilot project showed that customer requirements could be related to the perceived value through indexes. In addition, it is possible to visualize the aspects in which greater value is generated and others in which it is partially or totally lost. The model supports a better understanding of the concept of value and how to capture it to keep customer satisfaction conditions. VAM allows comparisons between different customer views of value, the value generated and lost regarding the process and product, and the value generated and lost in various projects. Moreover, it is possible to see the evolution of the value generated over time with several revisions.

The second question studied the generation and losses of value in the traditional design process, providing evidence of how the traditional process responds in a minimal way to the value expected by the clients concerning different conditions of satisfaction of both the product and the process. The results showed lower value losses in the product and higher value losses in the process. The customer who receives the least value during the design process are the builders, while the designers are who get the lowest value in the product. On the other hand, the end-users obtain the most value in both the process and the product. Value losses resulting from different customer viewpoints (default value losses) are low and are present in the process rather than in the product. Therefore, the main value losses are related to the project's performance and are not due to conflicting perspectives among the different customers.

The third question studied the generation and loss of value in the design process of a TVD project. It provided evidence of the evolution of the project value regarding the incorporation of actions, practices, or tools linked to TVD. The results permitted visualizing the evolution of cost and value towards a target cost and value in a very similar way, respectively, making their comparison feasible. This research shows that cost minimization to reach the target cost can be achieved without detriment of value. In addition, this study provides evidence of the current emphasis on cost versus value. This knowledge can contribute to focus attention on value attributes and balance the cost-value relationship in TVD projects.

## 5.2 CONTRIBUTIONS

This dissertation offers several contributions to the body of knowledge of architecture, engineering, and construction management. The most important contribution means a better understanding of value generation in traditional and TVD projects. This section discusses the theoretical and practical contributions of the research.

### 5.2.1 Theoretical contributions

The theoretical contributions of this dissertation are based on three main aspects: development of a novel model, creation of indexes, and supplements to previous methods and coefficients.

a) Development of Value Analysis Model (VAM)

The value analysis model (VAM) developed in this study contributes to evaluating and measuring the value generated in the design process and product in the AEC industry, permitting the early identification of value losses. The VAM contributes to quantifying the value expectations of different customers present in the design process, the value generated from customer perceptions, and the resulting value losses by calculating value measurement indexes.

The VAM allows having a better understanding of the concept of value and value losses through the visualization and classification of project attributes (see figure 3-2). In addition, the model permits to visualize when the incorporation of the attributes increases, decreases, or maintains the value of the project. The model provides a common measurement language for all value attributes. This aspect is essential since value attributes are very heterogeneous and with multiple units of measurement. In addition, the model contributes to the numerical and graphical identification of value losses.

The VAM allows a holistic view of the entire process encompassing the total measurement, considering the process, product, and customer. In addition, the percentage of incorporation of each type of attribute in design decisions provides clarity on where to allocate the most significant efforts and resources and on which aspects to assign moderate efforts and resources. On the other hand, it is possible to compare expected and generated value per customer, differences between process and product, and differences between projects. Also, it is feasible to see the evolution of the value generated over time with several revisions. In addition, VAM measurements make possible the comparison between cost and value. The model illustrates in very similar terms the target costing with the measurement and value evolution, which makes their comparison feasible: target cost with potential value, the allowable cost with the desired value, and the percentage of fulfillment of target value or target cost, respectively.

b) Creation of indexes

VAM incorporates four indexes: desired value index (DVI), potential value index (PVI), desired value generated (DVG), and potential value generated (PVG). Also, the model incorporates two main types of value losses: desired value loss and potential value loss, and these with a second categorization: default value loss, as a result of opposite perspectives of customer, and performance value loss, as a result of value management of the project.

c) Supplements to previous methods and coefficients

The VAM (Giménez et al., 2020) is based on the classification of attributes proposed in the theory of attractive quality (Kano et al., 1984). VAM incorporates a value for each type of attribute according to whether they are present or absent and their impact on customer satisfaction. Figure 2-4 (a) shows the valuations proposed in VAM for each attribute based on the behavior graph of Kano's attributes. These values permit the calculation of desired, potential, and generated value indexes.

Additionally, this research complemented the coefficient of satisfaction (CS) (Berger et al., 1993) by incorporating the reverse attributes into the equations. Berger et al. (1993) had omitted it because a reverse attribute can be written in inverse by becoming any of the other four types of attributes. However, when using the view of different types of customers, it was essential to keep the reverse attributes to make the opposite or contradictory views between them transparent. These innovations to the CS are shown in equations 3 and 4 and figure 2-3 of chapter 2.

In summary, VAM could be considered a value estimation method that focuses on the capture, flow, and traceability of customer requirements throughout the project using metrics and indicators to measure different value conditions. This model represents an appropriate method that links customer requirements capture with the continuous measurement of value generated while identifying value losses on time. Therefore, this model responds to the research gap identified through the literature review on current practices related to the value generation of the design process within the AEC industry related to a lack of adequate value measurement methods. Thus, VAM is incorporated into the body of knowledge of value management.

### 5.2.2 Practical contributions

The value analysis model (VAM) has practical value within the AEC industry. It is useful for optimizing products and processes, as aspects for continuous process improvement are quickly identified on a stage-by-stage and project-by-project basis. VAM Encourages constant feedback and can provide superior value delivery. It allows the determination of parameters that add value for different stakeholders, thus informing designers where to direct resources and efforts to improve vital rather than trivial variables. In the practical implementation of VAM, the design team can consider the requirements of builders, owners, end-users, and other clients to maximize value. Through this approach, it is possible to obtain more benefits when implementing TVD on projects. Having a tool to assess and measure value generation while designing and costing is advantageous for teams applying or trying to apply this methodology efficiently.

Value benefits generally reported implicitly (not measured, only reported) can be made explicit (measured and traceable) through the use of VAM. These explicit metrics (quantification of value expectations, measurement of value generated from customer perceptions, and resulting value losses) can enable the inclusion of value-related metrics to traditional measures of project performance (time, cost, and productivity) since VAM provided a common language measurement for all value attributes. This common language allows comparison of process and product and cost to value. This research shows the increased emphasis on product (as a result) over the process and on cost versus value in

TVD projects. This knowledge can help focus attention on value attributes and balance the cost-value and process-output relationship in projects. This research also shows that cost minimization and target cost can be achieved without detriment to the value of TVD projects.

Value losses are identifiable from the design phase, allowing take measures to minimize them and maximize value. The model illustrates the attributes and satisfaction conditions in which there are more significant value losses, ordering them in an increasing or decreasing order. This order makes it feasible to plan actions and make decisions to improve the process and the product in an informed manner. The visualization of the value evolution makes it possible to review whether the value increases or decreases and whether this is due to the incorporation of actions, practices, or tools in the project's development. On the other hand, the transfer of these value losses from the design stage to the construction stage can also be avoided, along with the consequences related to productivity, time, and costs that this avoidance would represent.

On the other hand, the flexibility and adaptability of VAM allow researchers to conduct systematic studies searching for the value generated by applying innovative design and construction methods, different project delivery models, or the review of value under specific project satisfaction conditions, such as sustainability and safety attributes.

This model is a good tool for collaborative development, as it makes information and communication between the different stakeholders transparent, making requests clear from the early stages. In addition, the VAM is a helpful model that provides explicit information, which may be necessary for design-build projects involving many stakeholders or clients. VAM encourages conversations between key stakeholders, allows thinking about the value to the next customer in the process, and contributes to properly capturing requirements. With the use of VAM, the proportion of value losses resulting from differences in customer interests versus those related to project performance and performance can be assessed, contributing to joint decision making. VAM can help reach agreements to establish the value of a project by showing the different customer perspectives and directing them towards a similar prioritization path that seeks the best possible value (the target value).

## 5.3 LIMITATIONS

The general limitations of this dissertation are based on several aspects: limitations of the study, limitations of the model developed for value measurement and analysis (VAM), and limitations of TVD implementation in the Chilean context.

a) Limitations of the study

The VAM pilot tests were initially focused on two housing projects. The results of its implementation were based on the experience of three case studies of traditional projects and one TVD project. Therefore, its application in projects was carried out in a small number of projects and only housing projects. For this reason, the results should not be interpreted as universal for all types of construction projects. However, it is believed that VAM applies to other sectors, such as industrial construction, and infrastructure. If generalization, benchmarking, or comparative analysis is desired, it is recommended that a larger number and other types of projects be incorporated.

On the other hand, this study considered attributes associated with the product and the design process, but not with the construction or production process of the project execution.

b) Limitations of VAM

Concerning the use and application of VAM, it has some limitations. Classifying the attributes using a two-dimensional survey is necessary to calculate the desired and potential value indexes. By consulting in a functional (positive) and dysfunctional (negative) survey often confuses the respondent or can become very long if the list of attributes is extensive. On the other hand, the wording of the attributes should be based on more general customer needs and requirements without obtaining detailed specifications. Very exact specifications were not tested in any of the cases with the model.

On the other hand, in the valuations given for each attribute present or absent, only values of 0, 1, and -1 were incorporated, ignoring the case of the attractive attribute in which, if present, it can have a value of 1 or higher, and the case of the must-be attribute in which, if absent, it can have a value of -1 or lower. This decision was made to facilitate the model calculations.

There are many types of clients that can be consulted; however, the access to information is not the same. End-users are one of the most important customers, but access to their answers was not always easy. In the case of the single-family house in Spain, as there was only one end-user, the responses were consulted through a personal interview and a survey in an expedited manner. In the case of Chile, it was not possible to access the end user's information; and in the case of Venezuela, out of a total of 250 families consulted, information was obtained from 57.

c) Limitations of TVD implementation in the Chilean context

Regarding the limitations encountered with TVD, this is a relatively new methodology, and there are few projects completed, most of them testing and developing modifications in the process (Ballard, 2011). In general, TVD has been incorporated in projects related to the health sector in the US (Rybkowski, 2009; Ballard, 2012b; Do et al., 2014 ;Zimina et al., 2012; Rybkowski et al., 2012) and education (Ballard, 2011). However, there are isolated cases of application in other sectors, such as energy efficiency facilities (Lee, 2012) and real estate projects in Brazil and Germany (Kron & von der Haar, 2016; Neto et al., 2016; Oliva et al., 2016). Therefore, it was not possible to find complete access to information on projects already developed with the TVD methodology to evaluate and measure the generation of value in any of them.

For this reason, based on the literature, TVD was implemented in a Chilean project, finding difficulties and limitations in the process. In the Chilean construction industry, the traditional type of management is deeply rooted, and there is a lack of knowledge and understanding of what TVD is. Chapter 4 shows the main difficulties encountered for implementing TVD, which are associated with the continuous cost calculation due to the design iterations, the application of the Big Room, and collaborative planning. The continuity and speed of cost estimation were some of the significant constraints encountered in the company, so the centralized cost department made the costs associated with all project items to each committee to make the corresponding estimates. This action contributed significantly to the continuous and rapid estimation of costs. Applying a big room or colocation within the company's projects would incorporate drastic changes in the conformation of work teams and the infrastructure of corporate spaces, which is why virtual meetings were recommended to reduce latency times in principle. Regarding collaborative planning, the use of ICE sessions supported by BIM is recommended.

## 5.4 FUTURE RESEARCH

The following suggestions will be helpful to complement this dissertation and enhance the knowledge about the VAM and TVD.

Future research could focus on extending the application of the VAM to other phases of the project life cycle, such as construction and operation, incorporating in the list of attributes aspects related to the construction process and not only to the design process. In addition, it would be of great value to evaluate a higher number of projects of different types to create a benchmarking study of expected value at the country or Latin American level.

Future research could also consider how BIM technologies, sustainability, safety, industrialization, or new practices associated with project management affect the generation of value in the design and construction process and the product.

It is essential to highlight that within the TVD methodology; systematic actions are carried out to achieve the target cost. It would be interesting to use an analogous method with the value, a "target valuing" that allows incorporating concrete actions to achieve the desired (allowable) and potential value (target value). With the use of VAM, the gap between the expected value and the value generated, known as value loss, can be visualized. By identifying these value losses and why they occur, actions can be planned to minimize them and thus achieve the target value. It is recommended in future TVD applications to incorporate the measurements associated with value using the VAM.

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**A N E X X E S**

# ANNEX 3-1. PRODUCT ATTRIBUTES RELATED TO CONDITIONS OF SATISFACTION

| Condition of satisfaction | Related attributes | CS1 | Ideal % | Real % | CS2 | Ideal % | Real % | CS3 | Ideal % | Real % |
|---|---|---|---|---|---|---|---|---|---|---|
| | Soundproofing | | | | M | 100% | 92% | O | 100% | 33% |
| | Thermal comfort | | | | M | 100% | 100% | M | 100% | 33% |
| | Wide and comfortable spaces | | | | M | 100% | 75% | | | |
| | Good-size bathrooms, kitchen, and toilets | | | | | | | M | 100% | 71% |
| | Large bedrooms | | | | | | | M | 100% | 57% |
| | Space for comfortable living and dining | | | | | | | M | 100% | 75% |
| | Good distribution | | | | | | | M | 100% | 79% |
| **Home comfort** | Good natural lighting | | | | M | 100% | 92% | M | 100% | 82% |
| | Good natural ventilation | | | | M | 100% | 92% | M | 100% | 89% |
| | Safe | | | | M | 100% | 92% | O | 100% | 68% |
| | Functional | M | 100% | 44% | M | 100% | 92% | | | |
| | Internal privacy (with other inhabitants of the house) | | | | M | 100% | 92% | | | |
| | External privacy (with respect to neighbors) | | | | O | 100% | 75% | M | 100% | 64% |
| | Storage | | | | M | 100% | 100% | O | 100% | 50% |
| | Master bedroom on the ground floor | | | | O | 100% | 100% | | | |
| | Entertainment and leisure areas | | | | | | | M | 100% | 68% |
| | Safe urban area | | | | | | | M | 100% | 89% |
| | Well-lit streets and community areas | | | | | | | M | 100% | 65% |
| | Connectivity | | | | | | | M | 100% | 57% |
| | Special spaces for pets (for walking, bathing) | | | | | | | A | 0-100% | 14% |
| | Commercial premises of first necessity | | | | | | | A | 0-100% | 7% |
| | Swimming pool | | | | | | | A | 0-100% | 21% |
| **Community comfort** | Electric plant | | | | | | | A | 0-100% | 25% |
| | Active squares, jogging tracks or gyms | | | | | | | M | 100% | 39% |
| | Visitor parking spaces | | | | | | | M | 100% | 79% |
| | Irrigation system for green areas | | | | | | | O | 100% | 50% |
| | Water tank | | | | | | | M | 100% | 86% |
| | Covered parking spaces | | | | | | | O | 100% | 89% |
| | Primary access guardhouse with rain shelter | | | | | | | M | 100% | 75% |
| | Good location | O | 100% | 50% | M | 100% | 92% | O | 100% | 79% |
| | Low cost variability | O | 100% | 50% | | | | | | |
| | Low operating costs | | | | | | | M | 100% | 45% |
| **Finance and investment** | Low service costs (water, electricity, gas) | | | | M | 100% | 83% | | | |
| | Low replacement and maintenance costs | | | | M | 100% | 83% | | | |
| | Good cost/quality ratio | O | 100% | 40% | M | 100% | 92% | M | 100% | 83% |
| | Good cost/square meter ratio | M | 100% | 33% | M | 100% | 92% | M | 100% | 75% |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Competitive design | O | 100% | 40% | M | 100% | 92% | M | 100% | 86% |
| | Enough space to start a business at home | | | | R | 0% | 0% | | | |
| | Expansion possibilities | | | | R | 0% | 0% | | | |
| | Profitable product | O | 100% | 50% | | | | M | 100% | 58% |
| | The value is retained over time | O | 100% | 70% | M | 100% | 92% | M | 100% | 92% |
| **Performance** | Compliance with regulations | M | 100% | 90% | | | | | | |
| | Meets the customer's requirements | O | 100% | 70% | | | | | | |
| | Product stable during earthquakes and other events | M | 100% | 80% | M | 100% | 100% | M | 100% | 85% |
| | Easy to build | O | 100% | 35% | A | 0-100% | 67% | O | 100% | 88% |
| | A high percentage of repetitive elements | O | 100% | 45% | | | | | | |
| | Durable/quality materials | M | 100% | 60% | O | 100% | 92% | M | 100% | 90% |
| | Commercially available materials | O | 100% | 80% | I | 0% | 50% | O | 100% | 83% |
| | Easy-to-install materials | O | 100% | 80% | A | 0-100% | 50% | O | 100% | 90% |
| | No complaints | M | 100% | 58% | | | | | | |
| | Project delivered on time | | | | M | 100% | 58% | | | |
| | Quickly buildable | | | | | | | M | 100% | 83% |
| **Aesthetic** | Artificial lighting project | | | | M | 100% | 92% | | | |
| | Attractive access to urban planning | | | | | | | O | 100% | 64% |
| | Modern/current design | | | | | | | M | 100% | 75% |
| | Aesthetic | M | 100% | 50% | M | 100% | 92% | M | 100% | 75% |
| | Differentiating image | A | 0-100% | 75% | | | | | | |
| | Simple-single (not recharged) | | | | O | 100% | 50% | | | |
| | The image stays current for a long time | | | | M | 100% | 100% | O | 100% | 79% |
| **Innovation and technology** | Innovative product | M | 100% | 40% | M | 100% | 92% | | | |
| | Presenting basic technology (internet, telecommunications) | | | | | | | M | 100% | 42% |
| | Presenting cutting-edge technology (domotics or similar) | A | 0-100% | 60% | M | 100% | 92% | O | 100% | 7% |
| **Health and Sustainability** | Improves the quality of life of the community | M | 100% | 50% | | | | | | |
| | Improves the quality of life of the end user | O | 100% | 65% | | | | | | |
| | Sustainable/energy efficient | M | 100% | 55% | M | 100% | 75% | | | |
| | Abundant green areas | | | | M | 100% | 92% | M | 100% | 82% |
| | Bicycle path and parking | | | | | | | A | 0-100% | 4% |
| | Garbage rooms away from the residential and social area | | | | | | | M | 100% | 43% |
| | Green/common areas with a low level of maintenance | | | | | | | M | 100% | 54% |

ANNEX 3-2. PROCESS ATTRIBUTES RELATED TO CONDITIONS OF SATISFACTION

| Condition of Satisfaction | Related attributes | CS1 | Ideal % | Real % | CS2 | Ideal % | Real % | CS3 | Ideal % | Real % |
|---|---|---|---|---|---|---|---|---|---|---|
| **Tools and technology** | Use of 3D images and/or videos to better understand the design | | | | A | 0-100% | 58% | O | 100% | 50% |
| | Use of BIM between design and build | A | 0-100% | 50% | | | | | | |
| | Using BIM for specialty coordination | A | 0-100% | 55% | A | 0-100% | 42% | A | 0-100% | 0% |
| | Using BIM to virtually build and review constructability | | | | | | | A | 0-100% | 0% |
| | Technology with adequate capacity (software, hardware and netware) | M | 100% | 75% | M | 100% | 42% | O | 100% | 31% |
| | Handle several parallel design options | M | 100% | 44% | O | 100% | 58% | M | 100% | 63% |
| **Corporative environment** | Good communication and good working environment | M | 100% | 88% | | | | | | |
| | Well-paid | | | | | | | M | 100% | 44% |
| | Promote learning | | | | | | | M | 100% | 63% |
| | Provide technical and social expertise | | | | | | | M | 100% | 75% |
| | Sense of belonging to the team | | | | | | | O | 100% | 81% |
| | Low staff turnover | A | 0-100% | 67% | M | 100% | 58% | M | 100% | 63% |
| **Conflicts/Roles** | Good dispute resolution (No fights or setbacks) | | | | O | 100% | 50% | O | 100% | 75% |
| | Good relationship between designer and owner | | | | M | 100% | 63% | | | |
| | Consistency between design and budget | | | | | | | M | 100% | 63% |
| | Consistency between what is offered and what is delivered to the end user | | | | | | | M | 100% | 63% |
| | Consistency between design and execution | | | | | | | M | 100% | 69% |
| | Respects technical, local and national regulations | | | | | | | M | 100% | 88% |
| | Absolute freedom for the designer | | | | R | 0% | 8% | | | |
| | Let the designer be the one to build | | | | R | 0% | 8% | | | |
| **Constructability** | Inclusion of repetitive elements within the process | | | | | | | M | 100% | 56% |
| | Inclusion of standardization within the process | M | 100% | 69% | O | 100% | 58% | O | 100% | 44% |
| | Inclusion of industrialization within the process | M | 100% | 69% | A | 100% | 58% | O | 100% | 44% |
| | Inclusion of innovation within the process | O | 100% | 81% | A | 100% | 58% | O | 100% | 31% |
| | The design is constructible | | | | | | | M | 100% | 94% |
| | Integral design solution (external and internal)-(materials and finishes) | | | | M | 100% | 58% | M | 100% | 63% |
| **Information flow** | Low response time to information requests | M | 100% | 56% | | | | | | |
| | Low response time to change requests | M | 100% | 50% | O | 100% | 58% | M | 100% | 50% |
| | Clarity in design solution | | | | M | 100% | 58% | O | 100% | 69% |
| | Clarity in requests for information and solutions | M | 100% | 56% | M | 100% | 58% | M | 100% | 44% |
| | Clarity in customer requirements | M | 100% | 56% | M | 100% | 58% | A | 0-100% | 50% |
| | Formality in the documentation of changes. | M | 100% | 42% | O | 100% | 58% | O | 100% | 44% |
| | Information available to all those involved in the design | M | 100% | 44% | O | 100% | 58% | M | 100% | 69% |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Design update protocol | | | | | | | M | 100% | 44% |
| Deliverables | Generate deliverables ready to apply for permits | | | | | | | M | 100% | 75% |
| | Generate ready-to-build deliverables (Buildable drawings) | M | 100% | 31% | | | | M | 100% | 50% |
| | Generate clear deliverables, no modifications in execution | O | 100% | 50% | | | | O | 100% | 44% |
| | Use of standard format for orderly information | A | 0-100% | 75% | | | | M | 100% | 44% |
| | Generate metric and quantity information | M | 100% | 25% | | | | M | 100% | 44% |
| | Project with all necessary specifications and information | M | 100% | 50% | | | | M | 100% | 44% |
| | Deliverable without inconsistencies between specialties | M | 100% | 50% | | | | | | |
| Integration | Multidisciplinary contribution to decision-making | M | 100% | 81% | O | 100% | 58% | M | 100% | 69% |
| | Designer involved in construction | | | | A | 0-100% | 42% | O | 100% | 63% |
| | Early integration of construction professionals | M | 100% | 63% | O | 100% | 33% | M | 100% | 81% |
| | Objectives aligned with full optimization | M | 100% | 56% | O | 100% | 42% | M | 100% | 69% |
| | Multidisciplinary planning and collaborative design | M | 100% | 81% | O | 100% | 58% | M | 100% | 44% |
| | Long term relationship with suppliers and specialties | M | 100% | 30% | M | 100% | 58% | O | 100% | 75% |
| | Sharing risks and rewards | M | 100% | 42% | R | 0% | 25% | O | 67% | 56% |
| Times and costs | Commitment to meeting deadlines | M | 100% | 50% | M | 100% | 75% | M | 100% | 31% |
| | Knowledge of budget availability | M | 100% | 50% | M | 100% | 67% | M | 100% | 38% |
| | Incorporate cost changes simultaneously with design modifications | M | 100% | 31% | O | 100% | 58% | M | 100% | 56% |
| | Design project completed on the due date | | | | M | 100% | 75% | O | 100% | 38% |
| | Project delivered on the due date | | | | | | | O | 100% | 44% |

ANNEX 4-1. PROCESS CONDITIONS OF SATISFACTION.

| Conditions of Satisfaction (CoS) | Process Attributes | OW | DE | BU | PR | %ideal | %R0 | %R1 | %R2 |
|---|---|---|---|---|---|---|---|---|---|
| **Information flow / Communications** | Low response time to information requests | O | A | M | M | 100% | 63% | 69% | 88% |
| | Low response time to requests for modifications | O | O | M | M | 100% | 53% | 61% | 67% |
| | Clarity in requests for information and solutions | M | M | M | M | 100% | 66% | 67% | 83% |
| | Clarity in the background and requirements of the clients | M | M | O | M | 100% | 64% | 78% | 83% |
| | Formality in the documentation of failures, problems and modifications. | M | O | M | M | 100% | 68% | 72% | 83% |
| | Important information visible and available to all involved in the design | M | M | O | M | 100% | 64% | 89% | 75% |
| **times and costs** | Commitment to meeting deadlines | M | M | M | M | 100% | 59% | 45% | 83% |
| | Knowledge of budget availability by all those involved in the design | M | M | M | M | 100% | 43% | 75% | 75% |
| | Incorporate cost changes simultaneously with design modifications | R | O | M | M | 100% | 44% | 58% | 50% |
| **tools and technology** | Use of BIM-VDC technology between design and construction | A | A | A | A | 0-100 | 46% | 78% | 78% |
| | Using BIM for Specialty Coordination | A | A | A | A | 0-100 | 54% | 90% | 90% |
| | Technological means with adequate capacity (software,hardware and netware) | M | M | M | M | 100% | 63% | 65% | 75% |
| | To manage several parallel design options | M | I | I | M | 100% | 46% | 72% | 42% |
| **constructability** | Inclusion of standardization within the process | O | I | M | M | 100% | 63% | 60% | 67% |
| | Inclusion of industrialization within the process | O | A | M | M | 100% | 75% | 90% | 75% |
| | Inclusion of innovation within the process | O | A | A | O | 100% | 75% | 73% | 67% |
| **integration** | Multidisciplinary contribution to decision making | M | O | I | M | 100% | 81% | 83% | 75% |
| | Early integration of construction professionals | M | M | A | M | 100% | 72% | 86% | 67% |
| | Objectives aligned towards full optimization | M | O | I | M | 100% | 64% | 68% | 75% |
| | Multidisciplinary planning and collaborative design | M | O | O | M | 100% | 75% | 73% | 75% |
| | Long term relationship with suppliers | M | I | I | M | 100% | 79% | 67% | 75% |
| | Shared risks and rewards | M | M | M | M | 100% | 46% | 53% | 75% |
| **corporative environment** | Good communication and good working environment | M | M | O | M | 100% | 84% | 63% | 92% |
| | Low staff turnover | A | I | I | A | 0-100 | 64% | 78% | 67% |
| **deliverables** | Generate ready-to-build deliverables (Buildable drawings) | M | M | M | M | 100% | 72% | 42% | 67% |
| | Generate clear deliverables, no modifications in execution | O | A | A | O | 100% | 54% | 58% | 67% |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Use of standard format for orderly information | A | I | A | A | 0-100 | 67% | 67% | 67% |
| | Generate metric and quantity information | O | M | I | M | 100% | 47% | 40% | 67% |
| | Project with all necessary specifications and information | M | M | M | M | 100% | 54% | 55% | 67% |
| | Deliverable without inconsistencies between specialties | M | M | M | M | 100% | 64% | 63% | 67% |
| OW: Owner; DE: Designer; BU: Builder; PR: Priority | | | | | | | | | |

ANNEX 4-2. PRODUCT CONDITIONS OF SATISFACTION

| Conditions of Satisfaction (CoS) | Product Attributes | OW | DE | BU | PR | %ideal | %R0 | %R1 | %R2 |
|---|---|---|---|---|---|---|---|---|---|
| **home comfort** | Functional | O | O | M | M | 100% | 38% | 63% | 92% |
| **finance and investment** | Good Location | O | A | A | O | 100% | 63% | 63% | 92% |
| | Low cost variability | O | I | I | O | 100% | 59% | 69% | 83% |
| | Good cost/quality ratio | O | O | O | O | 100% | 57% | 88% | 83% |
| | Good cost / square meters | O | I | M | M | 100% | 66% | 75% | 92% |
| | Sellable / competitive design | O | O | A | O | 100% | 69% | 84% | 83% |
| | Profitable product | O | A | I | O | 100% | 69% | 75% | 75% |
| | To maintain its value over time | O | O | I | O | 100% | 59% | 88% | 67% |
| **performance** | Compliant with regulations | O | M | O | M | 100% | 53% | 72% | 100% |
| | That meets the customer's requirements | O | A | I | O | 100% | 69% | 72% | 92% |
| | Product stable to earthquakes and other events | O | M | O | M | 100% | 69% | 69% | 83% |
| | Easy to build | O | I | O | O | 100% | 84% | 81% | 92% |
| | High percentage of repetitive elements | A | O | O | O | 100% | 81% | 72% | 83% |
| | Durable materials | O | A | M | M | 100% | 84% | 84% | 83% |
| | Materials available on the market | O | A | I | O | 100% | 66% | 78% | 83% |
| | Easy to install materials | O | I | A | O | 100% | 91% | 75% | 75% |
| | No reclaims | O | O | M | M | 100% | 75% | 56% | 100% |
| **image** | Aesthetic | O | M | I | M | 100% | 63% | 94% | 88% |
| | Differentiating image | A | A | I | A | 0-100 | 53% | 75% | 75% |
| **innovation and technology** | Innovative | A | M | O | M | 100% | 81% | 66% | 75% |
| | Presenting cutting-edge technology | A | A | I | A | 0-100 | 53% | 63% | 75% |
| **health and sustainability** | To improve the quality of life of the community | O | A | M | M | 100% | 46% | 75% | 92% |
| | To improve the customer's quality of life | O | A | O | O | 100% | 59% | 59% | 83% |
| | Sustainable/energy efficient | A | M | I | M | 100% | 46% | 72% | 92% |
| OW: Owner; DE: Designer; BU: Builder; PR: Priority | | | | | | | | | |

ANNEX 4-2. TVD PRACTICES AND TOOLS LEARNED AND APPLIED IN TRAINING-ACTION PLAN (BASED ON TABLE 4-1)

| Training plan | Action plan | Practices | Tools |
|---|---|---|---|
| **TVD introduction workshop** | Review of difficulties in incorporating them into the company<br>Senior management meeting to determine target cost and allowable cost.<br>Project cost visibility.<br>Efforts to achieve the target cost<br>Committee creation and work (Cluster work)<br>Difficult to implement Big room in the company.<br>All committee meetings (Big-group = Big room meeting-ish)<br>Auditing meetings.<br>Challenging to incorporate Set-Based Design<br>The target cost and the budget are broken down and tracked within clusters<br>Visibility of project objectives<br>Establishment of value attributes by clients.<br>Establishment of satisfaction conditions | 1-9. TVD Nine Foundational Practices<br>1. Engage deeply with the client to establish the target-value.<br>7. Work in small and diverse groups<br>8. Work in a Big Room<br>9. Conduct Retrospectives throughout the process<br>10. Cross-functional teams<br>15. Sub targets cost by teams<br>19. Projects are single-purpose networks of commitments<br>22. All team members understand the business case and stakeholder values<br>23. Set Targets for Values and Conditions of Satisfaction<br>33. Promote transparent communication | 1. Target costing<br>6. Formal retrospectives<br>7. Plus and delta activity;<br>8. Big-group meetings and Short co-design sessions<br>13. Pareto analysis by committee<br>18. Set Based Design<br>19. TVD update charts |
| **Constructability workshop** | Inclusion of industrialization, standardization, prefabrication.<br>Design solutions are developed with cost, schedule, and constructability as design criteria.<br>Constructability improvement proposals<br>Committee Meetings<br>Workshop attendance | 5. Concurrently design the product and the process in design sets<br>12. Balance designer and constructor (team members) interests<br>13. Early integration of designers and builders<br>17. Intentionally build relationships on projects<br>18. Optimize the whole project<br>21. Design solutions are developed with constructability as design criteria. | 3. Functional analysis/ Value engineering<br>20. Standarization |
| **CBA workshop** | Committee Meetings<br>Collaborative process | 16. Best value instead of lowest first cost | 17. CBA decision-making |
| **Innovation workshop and A3 thinking workshop** | Plus-delta activity<br>Design Thinking+Kaizen event(ish)<br>Lessons Learned Review | 2. Lead the design effort for learning and innovation.<br>27.Continuity of staff to retain the knowledge<br>28. Capture of lessons learned,<br>29. Lean set of tools to eliminate process waste<br>35. Encourages the discussion of problems and solutions<br>36. Prioritizes continuous but durable improvements over time instead of more radical improvements | 10. PDCA;<br>12. 5-Why™;<br>16. A3 report;<br>21. One-page improvement reports<br>25. Visual management tools<br>27. Prototyping<br>31. Design Thinking<br>32. Kaizen event |

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|---|---|---|---|
| **IPD workshop** | Balance owners, users, designers and builders' interests.<br>Review of value attributes by customer<br>Aligning team member interests<br>Collaborative actions to achieve target cost<br>Continuous estimating<br>To expand the use of BIM<br>Committee Meetings<br>Align project ends, means, and constraints.<br>Achievement search of sub-target cost aiming at the target cost fulfilment<br>Design solutions are developed with cost, schedule, and constructability as design criteria.<br>The company uses Last planner system ® in building stages.<br>Industry-Academy Alliance for Research in Linguistic Action | 3. Design to a detailed estimate.<br>4. Collaboratively plan and re-plan the project.<br>6. Design and detail in the sequence of the customer who will use it<br>11. Long term relationships with suppliers.<br>14. Early incorporation of main suppliers and contractors<br>17. Intentionally build relationships on projects<br>18. Optimize the whole project<br>Projects are single-purpose networks of commitments. | 4. Last Planner System®<br>8. Big-group meetings and Short co-design sessions<br>19. TVD update charts |
| **BIM workshop** | Collaborative actions to achieve target cost<br>Continuous estimating<br>To expand the use of BIM<br>Committee Meetings | 3. Design to a detailed estimate.<br>4. Collaboratively plan and re-plan the project. | 2. nD model (3D,4D…)<br>15. Building Information Model (BIM),<br>19. TVD update charts |