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Value assessment in the traditional housing design: Case studies applying a value analysis model

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ABSTRACT

The traditional design approach faces difficulties in adequately responding to the value expected by customers. This research explores the generation and loss of value in the traditional housing design to understand how it responds to customer needs based on different conditions of satisfaction and identify the most common value losses. The novel Value Analysis Model (VAM) is applied in three traditional housing design projects as case studies to explore the desired, potential, and generated value for four typical customers: owners, designers, builders, and end-users. The main results quantitatively show that the traditional housing design process does not meet the value expected by customers; the builders and the designers obtain less value in the process, and the product, respectively; and both the end-user and the owner are the customers who receive more value. This paper incorporates the value losses associated with differences in the criteria of the various project stakeholders (default) and losses resulting from poor project performance. According to the findings, the most widespread value losses are associated with the project performance itself rather than differences in customers' perceptions. The main practical contribution is that the value benefits become explicit (measurable and traceable) through VAM. These explicit value metrics can be included alongside traditional project performance measures to provide a customer-centric perspective. For teams attempting to design efficiently, having a tool to assess and measure value generation during creating is important because value losses can be detected early.

1. Introduction

Design is a systematic process for identifying, exploring, and exploiting value opportunities [1]. 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 [2]. The design process must deliver value to customers within their satisfaction conditions, which typically concern cost, time, and quality [3,4]. There may also be other value conditions such as sustainability, comfort, cultural appropriateness, durability, aesthetics/appearance, flexibility, operation and maintenance, safety, and environmental aspects, as well as potential benefits, such as problem and complaint management agreements or conflict resolution [5–8].

However, 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 [9–11], losses in other aspects more related to the design process itself [2,12,13], or its inability to meet customer value expectations [14,15]. For the purposes of this study, traditional design is the building design process that works separately from building construction [16,17]. Differences between traditional design and the other types of novel design are established based on the process and the technologies and communications [16], the pursuit of innovation, simplicity of use and information gathering to improve the constructability and performance of the project [18–20] or teams' integration [21,22].

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Concerning technologies, communications, and information flow, two-dimensional CAD systems are the AEC industry's most widely used information technologies [20,23]. There are also uses for three-dimensional drawing programs without physical attributes, such as SketchUp or similar, which are used in architectural design because they have the advantage of building fast, lightweight models and the flexibility for changes, but do not present intelligent information [19].

Regarding team integration, fragmentation characterizes the project team in the traditional design. This traditional way is considered when there is no integration between the owner, designer, and builder, or when it presents fragmented and strongly hierarchical teams [24,25]. Usually, the designer and owner are on the project from the pre-design stage, and some design consultants may be incorporated into the design development. While the builder is incorporated into the construction stages. These characteristics are evident in the design-bid-build method (DBB) [26,27].

On the other hand, usually the value generation is related to achieving the project goals to fulfilling the real purpose of its implementation [28] or evaluating and analyzing performance based on cost, time, and quality indicators [4,29]. However, current views consider this focus insufficient, reformulating it to strike a balance in measuring performance and incorporating a value-centered vision [29,30]. This vision includes aspects related to people, products, and resources; such as customer and project team satisfaction, environment, and technology [31,32].

Additionally, measuring value is usually in the project's final stage through an objective perspective and by reviewing whether the cost and time objectives have been fulfilled [33]. Understanding value as the satisfaction of customer needs and transforming customers' subjective and ambiguous statements into measurable values is not trivial; it requires logical processes and qualification and quantification methods [4,34] For this reason, value benefits are usually implicit, i.e., only reported but not measured or quantified [35,36]. In some cases, value has been assessed using word clusters, ranking of degree of importance, or a liker scale [37–40] Through the use of the recently developed Value Analysis Model (VAM), the value benefits are made explicit (measurable and traceable) [41]. These explicit value metrics (value expectations, value generated from customer perceptions, and value losses) allow determining and monitoring the parameters that add value for different stakeholders, thus informing designers where to direct resources and efforts.

This research applied VAM in three housing projects as case studies to answer How does traditional housing-design process generates and loses value? To answer this question, the authors explore two operational questions: (1) How does the design respond to the needs of different clients with diverse (or conflicting) satisfaction conditions, and (2) What are the most frequent value losses?

2. Background

2.1. Value assessment

Different value concepts 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 [3,42,43]. Value is often associated with monetary value, representing the economic view of market exchange value [44,45]. However, it is essential to distinguish between cost and value. Things can have significant aesthetic, sentimental, scientific, moral, political, or personal value but have little or no economic value, and viceversa [46]. On the other hand, the term "value loss" was introduced by [47] to describe the portion of value that is not given, although its provision is potentially possible. This idea is a means to assess value relative to the best possible value or the value that was actually achieved.

According to Giménez et al. [41], there are factors that influence the value generation process; these are (1) life cycle cost minimization; (2) the pursuit of customer satisfaction; (3) integrated solutions for requirements fulfillment; (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 value losses. These factors result from integrating several value perspectives [15,47,48].On the other hand, the simultaneous development of the process and the product is considered an opportunity to generate value [49,50]. Value can be maximized when needs are accurately determined and are maximally satisfied by the product produced and the process employed to produce it [51].

2.2. Value generation in the traditional housing design process

The design process includes fields of general layout, landscape, architecture, structure, MEP (Mechanical, Electrical & Plumbing), and investment estimation [19]. It also includes tasks related to collecting requirements, defining the scope, estimating activity resources and duration, developing a schedule, and planning cost, quality, communications, risk management, procurements, and stakeholder management [52,53].

Value generation may be present in both the product and the process. In residential buildings design, the value generation focuses on trying to achieve conditions of satisfaction related to what the owner or end-user wants in the product such as financial aspects, socio-cultural perceptions, cultural values, quality and well-being, image, spatial qualities and environmental quality [8,54], which affect the general psychology and behavior of the project's inhabitants [37]. Generally, the product is expected to achieve attributes related to aspects of comfort (e.g., visual, acoustic, technological, thermal, etc.), structural, technical and personal safety, shapes, dimensions and enclosures, image, flexibility and customization, privacy, sense of community, natural lighting, among others [8,37,54–57]. In contrast, the attributes related to the process are more focused on the internal design clients: architects, engineers and designers and can be applied to all types of building construction projects. These process attributes in general are related to relationships between the owner and designers [58–60], constructability aspects [59,61–63], deliverables and required documentation [35,61,62], information flow and communications between the different stakeholders[64–66], technological aspects [60,61], planning, cost and schedule issues [36,59,61,63].

3. Research method

3.1. Overall approach

The research strategy is an analytical study 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 [67]; it identifies patterns and the causes of phenomena and provides data to evaluate processes, individuals, or environments [68]. According to Yin [67], 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. The goal of this paper is to quantitatively analyze the value attributes of the traditional residential construction process and product design from different clients' perspectives, which would be the criteria for interpreting the case studies.

This study addressed the following research question: How does traditional housing-design process generates and loses value? The authors explore this question by answering two operational questions: (1) How does the traditional housing design process respond to customers' needs under different satisfaction conditions? and (2) What are the most frequent Value Loss?

The study propositions of this research are to understand the generation and loss of value in the traditional housing design process, explore whether the client's needs are actually met based on different satisfaction conditions and identify the most common value losses. The proposition is to verify quantitatively the low value generated by the traditional housing design process. It is also thought that the most significant value losses are 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 a multiple-case study approach to three traditional housing design projects. The multiple-case study approach, considering different contexts, can generate more robust and generalizable results [67,69].

As stated in the introduction, the authors applied the VAM [41] for case study analysis to link data to propositions. This model is applied to understand and monitor value creation during the design process. Data were collected in three cases through interviews, focus groups, and surveys to obtain information on both the product and the design process.

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. These projects were selected based on their different characteristics of scope, user profiles, and level of design progress, in addition to the researchers' access to the customers 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 level of analysis was simultaneous and individual and then collective. Table 1 depicts the characteristics of the three projects.

Case study 1 (CS1) was a project in the preliminary stages of the design process, which comprises 252 housing units, delivered in one residential building of 15 floors and two underground levels. This project is performed by a real estate and construction company located in Chile in 2019. The project was developed in Chile by two partnering companies, a real estate company designed it and the constructor built it.

Case study 2 (CS2) was a single-family project located in Spain. The project was in the construction stage at the beginning of 2020; thus, the design was already completed, and the owner contracted the design and construction separately. Hence, an architectural studio designed the single-family house, and then a constructor built it.

Case study 3 (CS3) was a multifamily housing project with six development phases located in Venezuela. It consists of 250 housing units delivered in townhouses and low-rise buildings. By early 2020, five development phases were already inhabited, and the sixth phase was under construction. A real estate construction company was performing the design and construction. It is important to highlight that the process was not an integrated work despite being only one company. The design and the construction division were separate departments and worked separately.

3.3. Data collection

Data collection was conducted through interviews, focus groups, and surveys. In the first two cases, the data collection process was conducted in person. Due to the 2019 coronavirus disease (COVID-19) pandemic, data collection was conducted online through virtual interviews and surveys for the third case. The objective of the interviews and focus groups was to establish an attributes list adapted to the projects' process and product. The survey objective was to understand how the clients see the attributes and classify them and understand the requirements development level.

In CS1, data were collected mainly through surveys and focus group meetings. Eight professionals from the company's different technical areas and three customers (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 (both owner and end-user), two architects from the architectural firm (designer), and two construction engineers from the construction company (builder). In CS3, online (due to the COVID-19 pandemic) interviews and questionnaires were considering the four different types of clients: owner (represented by two shareholders), designer (an architect), builder (two construction professionals), and 58 end users. In the latter case, four sales professionals served as links with the projects' end-users.

It is essential to highlight the differences between the three 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 who hires the services of the architectural firm and the construction company only once; therefore, the owner has no experience in the project's execution. 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.

3.4. Data analysis

To measure the value, the present work relies on an existing model, the Value Analysis Model [41], which consists of requirement capture, value generation, and comparison. In the next section, the VAM is explained in detail.

Table 1
Case study characteristics.

Case study	Year	Type	Socioeconomic level	Design process status	Housing units
1. Chile	2019	High-rise building	Lower-middle income	Preliminary design	252
2. Spain	2020	Single-family housing	High income	Under construction	1
3. Venezuela	2020	Multifamily housing	Higher-middle income	Five built phases; last phase: under construction	250

4. Value analysis model

The VAM measures the generation of value expected by clients and identifies value losses based on indexes of desired, potential and generated value, identifying value losses and value-fulfillment percentages in the design-build process. Fig. 1 summarizes the stages and steps of the VAM, which are explained below.

4.1. Stage 1: Requirement capture

4.1.1. Customer identification

The VMA's first step is to identify the customers who participate in the design process because the value must be measured separately by customers or groups of customers. This research evaluated the following customers: designers, builders, end-users, and owners.

4.1.2. Attribute analysis

This analysis includes creating a list of attributes based on customer requirements and classifying them according to five types of attributes proposed by Kano et al.[70]. 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 and community comfort, performance, finance and investment, aesthetics, innovation, technology, health, and sustainability.

A two-dimensional questionnaire was prepared to classify each attribute. In this way, the attributes were classified as must-be (M), one-dimensional (O), reverse (R), attractive (A), and indifferent (I) based on the combination of the answers to the two questions. Kano et al. [70] define attributes as follows:

(1) M attribute is an essential requirement and 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.
(2) attribute is a linear kind of requirement. When it is met, customer satisfaction increases. However, when it is unmet, customer satisfaction decreases.
(3) R attribute is customers dislike. The presence of these attributes causes customer dissatisfaction, and their absence causes satisfaction.
(4) A attribute generates a great satisfaction if it is 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.
(5) I attribute is a no-preference requirement, implying that the customer is indifferent to the requirement.

4.1.3. Target indexes calculation

The attributes are related to value based on whether they are present or absent and their impact on customer satisfaction. VAM uses desired value (DVI) and potential value (PVI) indices that represent the minimum and maximum value, respectively, needed to achieve the customer's requirements. To calculate the DVI, only what is expected by the customer should be considered; therefore, it will be the number of O and R attributes (to incorporate and avoid them respectively) over the total number of 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.

4.1.4. Consideration of multiple customers

In the context of this research, value is defined as the fulfillment of the needs of different customers, considering their diverse visions, and the term "customer" will be used interchangeably with "client" and "stakeholder." For this reason, each customer involved in the project has a unique index of desired and potential value, different from those of the other customers. The diversity in these indexes results from the differences in customers' classifications of the attributes. According to Horton et al. [71], each attribute type has a customer effect that must be dealt with based on a business decision related to each attribute's optimal degree of presence. Table 2 summarizes them.

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

(1) Weighting factor (W). Priority is given to treating the attribute based on the customer with the highest W.
(2) MORAI criterion. The priority of attributes is based on the following order: M > O/R > A > I [41,72].

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 %, with W, the attribute should be treated as O, but with MORAI criterion, the attribute should be treated as M.

The authors combined both forms of prioritization, first using the MORAI criterion and then, if necessary, the W. In cases where there were conflicts between O and R (which are at the same level of the MORAI criterion), the W was used to finally prioritize the attribute. The MORAI criterion favors aligning all customers' interests toward the ideal degree of presence, resulting in project optimization. W was determined collaboratively based on the customer's importance, impact or knowledge of the product or process. For example, the end-user had more weight on the product than the internal design process (see Appendix A).

In this research, the authors realized that the differences in the attribute classifications for each customer could lead to value losses by generating a maximum possible achievable value. When value must be generated for a single customer, 100 % of the desired and potential value can be achieved. However, the customers' dif-

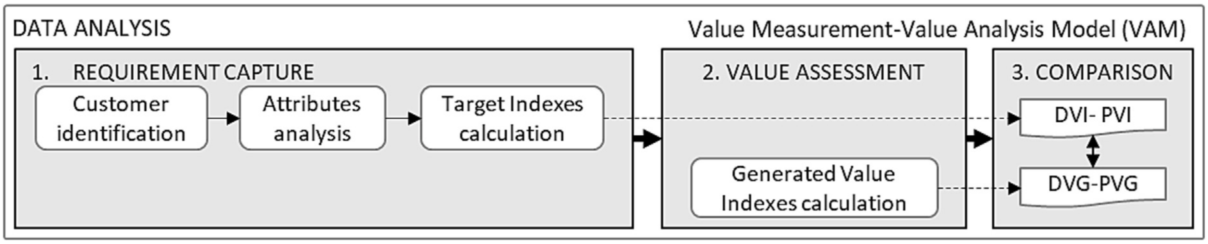

Fig. 1. Stages and steps of the VAM.

Table 2
Attribute perspectives.

Attribute	Customer effect	Business decision	The optimal degree 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 %

ferent points of view make it difficult to provide entire value for all customers, deciding which customer preferences should be privileged over others.

For example, if an attribute was classified R by one customer but was considered M by other customers, it will be managed as M according to prioritization. In this case, the optimal presence degree is 100 %, but there will be value loss for the customer who considers it R. These value losses can be measured after deciding how each attribute will be addressed.

4.2. Stage 2: Value assessment

4.2.1. Generated value indexes (GVI) calculation

The generated value indexes (GVI) are results of the value assessment stage, which are the Desired Value Generated (DVG) and the Potential Value Generated (PVG). A questionnaire with all attributes was used to quantify each attribute's degree of presence or absence. The DVG and PVG were calculated based on the valuations of each type of attribute (see Table 3), as shown in Eqs. (1) and (2).

Table 3
Attribute valuation.

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

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

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

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

On the other hand, based on the differences between each customer's classification and the optimal presence degree of the attributes after prioritization (Table 3), it was feasible to measure the maximum possible achievable value explained above, denoted as DVGmax and PVGmax.

4.3. Stage 3: Comparison

The DVI and PVI initially calculated are compared to the GVIs (DVG and PVG) in the design process. The result of this first comparison is the measurement of value losses, identified in two classes: (1) those related to the desired value (should be avoided), and (2) those related to the potential value (could be avoided). Fig. 2 is based on Drevland et al. [42] and illustrates the initial value indices, GVIs and value losses. Default and Performance value losses are incorporated in this paper. Comparing DVI and PVI to the maximum possible value identifies default value losses, i.e., those based on differences between customer perspectives; and comparing GVIs to the maximum possible value identifies performance value losses, i.e., those that are a consequence of the actions or decisions of the project.

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.

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 product, resulting in per-

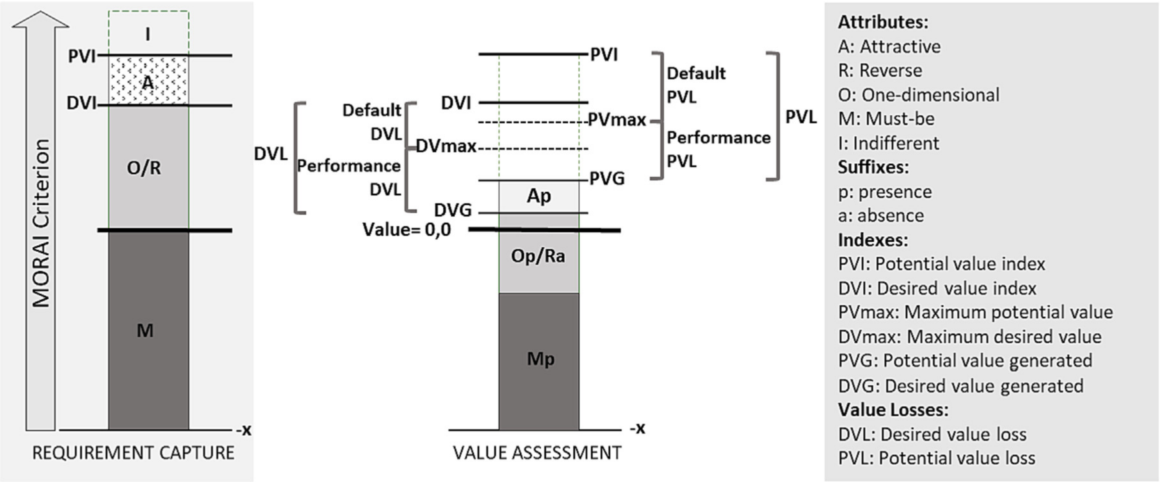

Fig. 2. Value indexes and value losses.

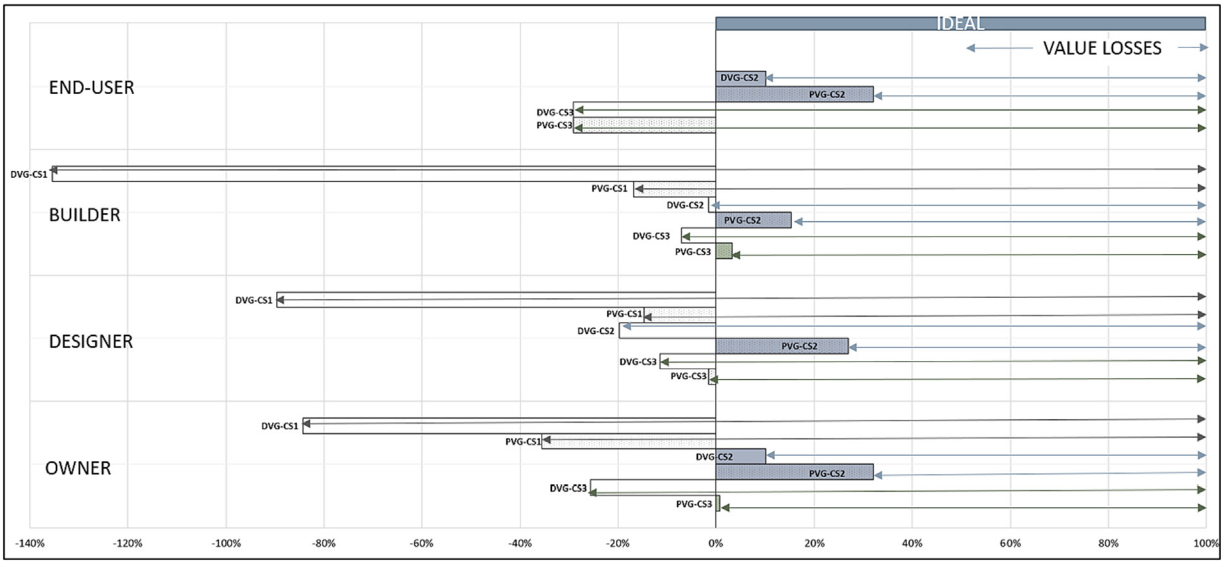

Fig. 3. Value generated and value losses for customers in the process.

centage values. This section also shows the value losses, representing the potential or desired value not provided. Appendixes B and C show the classification of each attribute by case study.

Fig. 3 illustrates the results of the process value analysis in the three cases, showing the percentages of value generated and value lost for each project and each customer. The value generated is insufficient for all customers. In most cases, DVG and PVG obtained negative values, or when they obtained positive values, they were deficient (<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) were generally higher than 100 %. Value loss is understood as the portion of value not provided, even if potentially possible [47]; therefore, 100 % of the DVI (desired value) should be provided and, ideally, 100 % of the PVI (potentially possible) can be provided. In CS1, the most significant losses correspond to builders, CS2 to designers, and CS3 to end users. These results are interesting since the highest value losses coincide with the customer with the lowest W (see appendix A). In CS1 and CS2, it also coincides that the customer 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.

Fig. 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. DVG and PVG obtained positive values; only three negative values were observed (two in CS1 and one in CS3). DVL and PVL were generally less than 100 %. 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 suffers 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.

Figs. 3 and 4 show that the greatest losses were found in the desired value rather than in the potential value. As discussed above, the desired value must be fulfilled, whereas the potential value is optional. It would be expected that PVLs would be higher than DVLs; however, 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 [14]. 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. Appendixes B and C show each attribute's ideal and real presence percentages in the three projects.

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 and Tillmann [73]. 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 [16].

5.2. Types of value loss

Table 4 shows the relationship between the default value losses and value losses performance. It can be observed. At a general level, it can be observed that the default value losses are lower than those of performance; this means that most value losses 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 many stakeholders are 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. In CS1, the default value losses are only present in the process, affecting the owner at a minimal scale (from 12 % to

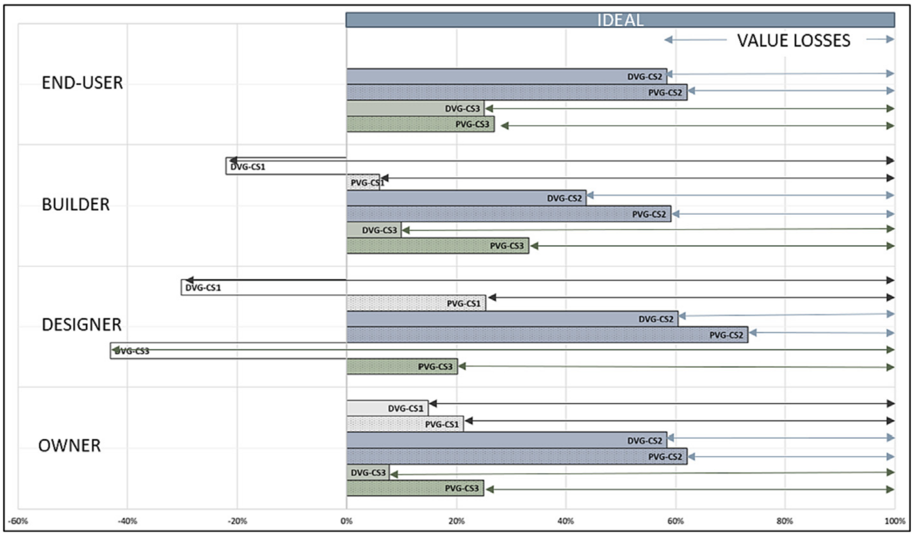

Fig. 4. Value generated and value losses for customers in the product.

Table 4
Types of value loss for customers.

			Process				Product			
			Owner	Designer	Builder	User	Owner	Designer	Builder	User
CS1	Default	DVL	14 %	0 %	0 %	n/c	0 %	0 %	0 %	n/c
		PVL	12 %	0 %	0 %	n/c	0 %	0 %	0 %	n/c
	Performance	DVL	86 %	100 %	100 %	n/c	100 %	100 %	100 %	n/c
		PVL	88 %	100 %	100 %	n/c	100 %	100 %	100 %	n/c
CS2	Default	DVL	0 %	43 %	0 %	0 %	0 %	0 %	0 %	0 %
		PVL	0 %	29 %	6 %	0 %	0 %	0 %	22 %	0 %
	Performance	DVL	100 %	57 %	100 %	100 %	100 %	100 %	100 %	100 %
		PVL	100 %	71 %	94 %	100 %	100 %	100 %	78 %	100 %
CS3	Default	DVL	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
		PVL	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
	Performance	DVL	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %
		PVL	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %

n/c: not consulted

Table 5
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 %**

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

5.3. Prioritization by customer

Table 5 shows the attributes classification, the priority based on the MORAI criteria, and the actual percentage of each attribute. It was expected that, first, the M and O attributes would be met, the R attributes would be avoided, and finally, the A attributes would be incorporated. However, it was observed in the process that the percentages of compliance with the M and O attributes were low (between 53 % and 66 %). In addition, the priority order does not seem clear; in CS1 and CS2, percentages higher than 50 % of attractive attributes were fulfilled without having met the M and O attributes. On the other hand, it was observed in CS2 that R attributes could not be avoided, being present at the 14 % level. No indifferent attributes were perceived in the prioritization, meaning that the attributes to which some customers were indifferent were classified differently by other customers.

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.

6. Conclusions

This research applied a novel model (VAM) to understand the generation and loss of value in the traditional housing 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. Then, these value expectations were compared with the generated value, allowing the early identification of the most common value losses within the design and their probable causes related to conflicts between the stakeholders' value perceptions or the project's performance.

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. The process satisfaction conditions associated with tools and technology, time and cost, and integration have a low presence percentage within the projects, as seen in Appendix C.

In general, the customer who obtains the least value in the process is the builder, while in the product, it is the designer. 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 project type or due to decisions made that meet the needs of other customers but not the needs of the designers.

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 project's performance and not due to conflicts of perspectives between different customers.

6.1. Research contributions

This paper contributes theoretically to the body of knowledge on value generation and has practical contributions to the AEC industry.

6.1.1. Theoretical contributions

This paper provides classifications of value losses, incorporating losses associated with differences in perspectives and criteria of different project stakeholders (default) and losses resulting from poor project performance.

6.1.2. Practical contributions

The main practical contribution of this research is that through the use of the Value Analysis Model (VAM), the value benefits are made explicit (measurable and traceable). These explicit value metrics (quantification of value expectations, measurement of value generated from customer perceptions and resulting value losses) can be included alongside traditional measures of project performance (time, cost and productivity), providing a customer-focused perspective and allowing value losses to be identified early in the design. Having a tool to assess and measure value generation while designing is advantageous for teams trying to design efficiently.

Other paper contributions demonstrate that the VAM facilitates understanding the value generation and losses in the building design process, measure how this process responds to the needs of diverse customers through different conditions of satisfaction, and evaluate the proportion of value losses resulting from differences in the customer's interests 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.

This research demonstrates the greater emphasis placed on the product than on the process. It also provides evidence of which customer receives greater or lesser value in the product and the design process. In the cases of this research, both owners and end users receive the most value (product and process). While the builders receive the least value in the process, the designers receive the least value in the product. In addition, the model illustrates in detail the attributes and satisfaction conditions where there is the most significant loss of value (see appendixes B and C), allowing informed action planning and decision making for process improvement.

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

6.2. Limitations and future research

This paper was based on the experience of three case studies. Therefore, the results are highly dependent on the context of each case, which is variable in any given construction project. However, some facts tend to be valid for all traditional housing projects. For example, separate design and construction management, greater concern for the product than the process, and generally low productivity. 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 (especially non-traditional and collaborative projects) by applying the VAM to analyze behavioral patterns based on their similarities and differences.

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. Additionally, more detailed studies of the value comparisons between traditional and more integrated and innovative design processes can be performed.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Appendix A. Weighting factor (W) for customers

	Owner		Designer		Builder		User	
CS1	41.6 %		27.6 %		30.8 %		–	
CS2	25 %		25 %		25 %		25 %	
	Owner		Designer		Builder		User	
	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 %

Appendix B. Product attributes related to conditions of satisfaction

Condition of satisfaction	Related attributes	CS1	Ideal %	Real %	CS2	Ideal %	Real %	CS3	Ideal %	Real %
Home comfort	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 %
	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 %			

(*continued on next page*)

Product attributes related to conditions of satisfaction (*continued*)

Condition of satisfaction	Related attributes	CS1	Ideal %	Real %	CS2	Ideal %	Real %	CS3	Ideal %	Real %
Community comfort	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 %
	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 %
Finance and investment	Good location	O	100 %	50 %	M	100 %	92 %	O	100 %	79 %
	Low cost variability	O	100 %	50 %						
	Low operating costs							M	100 %	45 %
	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 %

Product attributes related to conditions of satisfaction (*continued*)

Condition of satisfaction	Related attributes	CS1	Ideal %	Real %	CS2	Ideal %	Real %	CS3	Ideal %	Real %
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 %

Appendix C. 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 %

(*continued on next page*)

Process attributes related to conditions of satisfaction (*continued*)

Condition of Satisfaction	Related attributes	CS1	Ideal %	Real %	CS2	Ideal %	Real %	CS3	Ideal %	Real %
	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 %

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