# Integrating User-Centered practices in Configuration Systems development: Framework and Conceptual Modelling

**Irene Campo Gay**[1] and **Lars Hvam**[2]

**Abstract.** Developing configuration systems to support complex and highly engineered products can be a tedious task. Given the complicated nature of the process, both researchers and companies tend to overlook user interaction until later stages of the configuration process. This paper adopts a user-centered design process to develop configuration systems, emphasizing the difference between the customer and the configurator user. Moreover, we discuss the importance of making a clear distinction between the product, service, or process configured and the configuration system to be developed. In line with this, we propose a framework to empathize with the user in configuration system projects. Besides, we suggest a new user-experience tool to reflect user-centered outcomes in the conceptual modeling phase of configuration systems. We integrate the method into a consolidated conceptual model, the so-called product variant master. Finally, we test the procedure in a building construction configurator project which must deal with very versatile products. As a result, the configurator's profitability is enhanced by easing and promoting its use, optimizing the time spent on the configuration, and increasing efficiency by minimizing potential wrong choices.

## 1 INTRODUCTION

The use of configuration systems has been boosted by the benefits achieved through mass customization practices. Today's business environment is changing rapidly, and success requires the ability to meet the growing customer demand on customized products with short delivery times and at the same prices as mass-produced products [24]. In essence, configurators are expert systems that assist companies in both sales and engineering processes by automating and digitalizing the decision-making journey [12].

In these terms, configurators support different specification processes such as design, production, or sales [7]. Their use brings substantial benefits, including shorter lead times to generate specifications, fewer errors, and enhanced product design, among others [9; 11; 31; 32].

### 1.1 Motivation and aim

Within this framework, customer experience has recently caught the attention of researchers motivated by the potential increase in the customer's willingness to purchase mass-customized products. On this basis, the focus has been on what characteristics sales configurators should have to increase such benefits [33].

First, this paper aims to turn attention to User eXperience (UX) rather than customer experience alone and distinguish between the configurator user and the configurator end-customer. A case in point is a sales configurator, in which the user is not always the customer but a qualified salesperson. A more evident example is a B2B configurator, where users are generally specialized technicians. Secondly, the project intends to prioritize the configurator as the central artifact of the project development since, during configuration system projects, the product to be configured is usually the focal point.

The purpose is to empathize and understand the user in configuration system projects. Citing a quote from Henry Ford, *"If there is any one secret of success, it lies in the ability to get the other person's point of view and see things from that person's angle as well as from your own."*

This aim appeals directly to the User-Centered Design (UCD) approach, which solves a problem by understanding the users and their needs. The project's ultimate objective is to:

(i) portray the features for the configurator user in the configurator model,

(ii) develop a framework for generating User Interface (UI) based on user features,

(iii) improve the configurator in terms of increasing profitability, facilitating and promoting its use, optimizing the process, reducing time spent to configure a product, and raising accuracy by reducing potential wrong choices during the configuration journey.

In line with this scenario, the following two research questions (RQ) have been formulated:

***RQ 1:*** How can UCD be consolidated in the configuration system design and development?

***RQ 2:*** How can UCD be integrated during the knowledge modeling phase of Configuration Systems and represented in a conceptual model?

### 1.2 UCD concepts

Over the last decades, UX has become a buzzword in the human-computer interaction research area [8]. To promote UCD in configuration system projects, it is worth clarifying some concepts

[1] Department of Management Engineering, Technical University of Denmark, Denmark, email: ircag@dtu.dk
[2] Department of Management Engineering, Technical University of Denmark, Denmark, email: lahv@dtu.dk

since some are often used interchangeably, but they have different meanings. The most recognized definitions are described hereafter.

*Usability* determines how easy the user interface is to use [22] and refers not to the product attributes alone but to the interaction attribute with the product in a use context [14]. Thus, the core of usability—the ability to use the product—is the *utility*—the product usefulness. The usability term has also been defined as per the ISO Standard 9241-11 [29].

On the other hand, *UX* entails a broader concept—how a user interacts and experiences an artifact—encompassing usability.

Given what has been said, UCD concerns the process of engineering a particular experience—research and design. Moreover, *UCD* can be regarded as *human-centered design* formalized in the ISO standard 9241-210 [6].

### 1.3 Structure of the paper

The remainder of the paper is structured as follows. Section 2 presents the theoretical background on UX practices in both IT software in general and configuration systems in particular. Moreover, this section also provides an overview of UX representation on configuration conceptual modeling and presents the design thinking ideology to develop user-centered solutions. Section 3 explains the research method, presenting a novel theoretical framework and user-centered conceptual model. Section 4 presents the case study. Section 5 describes the research results achieved by implementing the new research approach described in section 3. Finally, section 6 discusses the results, answers the research questions, and presents the conclusions and directions for further work.

## 2 THEORETICAL BACKGROUND

This section presents the theoretical background divided into four subthemes. First, an overview of UX practices over the IT software field and the configuration system field are presented. Then, the current practices on UX representation on configurators' conceptual modeling are introduced. Finally, the design thinking ideology is presented as the approach to developing user-centered solutions.

### 2.1 UX in IT software systems

UX is recognized as one of the fundamental aspects of software systems' success as it can highly determine users' engagement. For that reason, research has focused mainly on the relationship between *human-computer interaction* and software engineering through UX practices. Nevertheless, the industry struggles to adopt a UX and even usability approach in their projects [2]. The reasons are the critical challenges that software companies face in their work with UX [16]. Consequently, diverse methods and standard procedures have been proposed over the last years, mainly aligned to the promising agile methodology, particularly scrum [1; 15; 25]. However, no specific practices have been defined for sales configurators [17] or configuration systems in general.

### 2.2 UX in configuration systems

Previous studies have researched UX on configuration systems. Mainly, efforts have focused on the correlation between a positive UX and an increased customer willingness to purchase the product [23]. To a lesser extent, some studies have identified and analyzed configurators' characteristics with an enhanced UX to procure such benefits. Trentin et al. and Sandrin et al. argue how diverse attributes on the UI do increase the hedonic and creative aspects of such configurators to achieve a better UX [26; 33].
However, these studies do not cover the use of UX practices within UCD in configuration systems' projects. In this regard, we aim at framing a more holistic picture, i.e., beyond the UI and Graphic User Interface (GUI) development.
Schäffer et al. introduced for the first time the user-centered concept in configuration systems in their work to enhance configurators' front ends [27]. They propose a user-centered front-end approach parallel to the configuration system development.
In our work, we take a more holistic perspective beyond the configurator's interface. The focal point is both (i) to empathize with the end-user and (ii) to reflect the knowledge in a conceptual model.

### 2.3 UX in configuration systems' conceptual modeling

A crucial step in configurator development entails scoping and representing the project knowledge in a model. Such a model evolves along with the design iterations. Hence, in the early project stages, conceptual models are used to organize the knowledge at a higher abstract level. This model corresponds to the phenomenon model stage in the knowledge progress process presented by Duffy et al. from the real world to an IT system. On more mature stages, knowledge representation is presented in information models, which entails a detailed structure of components, assemblies, and the relationships among them (see Figure 5).

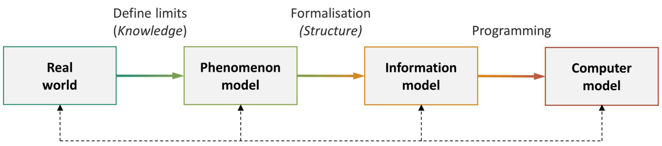


**Figure 1.** Knowledge model development from the real world to an IT system. Adapted from [5]

In the literature, we can find diverse models and methods to approach this task. These models portray the information concerning the configured artifact from different perspectives such as manufacturing, engineering, or customer-centric view.

For instance, we can find diverse conceptual models that address customer knowledge. Mortensen, Hvam, and Haug present in the so-called Product Variant Master (PVM) a customer view approach to depict the customer requirements [21]. Similarly, Hong et al. also suggest a customer-centered product modeling technique based on AND-OR trees [10]. Zhang also captures the customer requirements and integrates them in a configuration-oriented product model consisting of several sub-models [35].

However, no model considers a user-oriented description of the attributes [36]. In many cases, both individuals are the same person, particularly in the case of sales configurators. Still, there might be an intermediate, for example, a salesperson using the configurator in line with the customer specifications or a technical person in the case of product configurators. Therefore, there is a clear need to distinguish between customer knowledge and user knowledge and, also, to portray the user knowledge in the configurator's conceptual model.

## 2.4 Design thinking

We develop a solution based on a user-centered problem-solving method, design thinking. This method seeks to understand the user through an iterative method under a problem-driven and solution-based approach. There are few different design process models, though the most prominent are the one from *Stanford d.school* [30], the *IDEO design thinking* approach [13] and, the *designs council's double diamond* [4] (Fig.1).

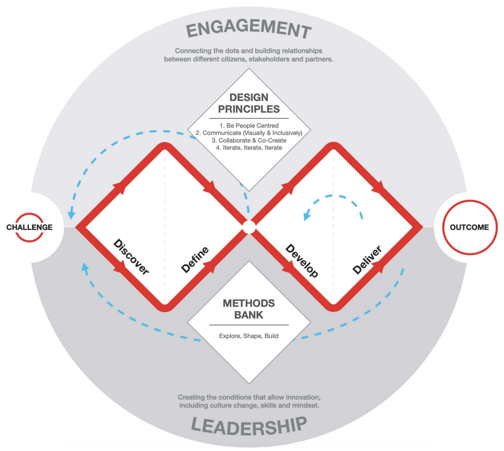


**Figure 2.** Design council's double diamond [4]

The fundamental steps are essentially the same, coinciding in that the iterative process must undergo diverging or abstract phases to later converge in more concrete stages. The key is to progressively develop more fidelity prototypes while the attention is centered on empathizing with the user. Hence, initially, simpler prototypes are modeled, promoting rapid prototyping. Later, the functionality degree and visual appearance are gradually increased.

The iterative approach of diverging and converging thinking has been explored within IT software development by Lindberg et al. [18]. However, in this study, the empathetic perspective of the design thinking process is set aside. The same approach was later applied to configuration systems [28]. Similarly, in this research, the creative aspects of design thinking are studied in terms of the motivation degree during configurators' development.

Hence, applying design thinking to develop empathetic and responsive users' needs in configuration systems is a novel focus with the potential to bring UCD and configuration systems together.

# 3 RESEARCH METHOD

First, state-of-the-art research on user experience best practices applied to configuration system projects has been carried out.

The project has been executed under the design science methodology usually applied to human-computer interfaces [19] to answer the formulated research questions. It focuses on developing innovative artifact designs under an iterative design process that supports its improvement through cyclical evaluations.

The project has been developed under a novel suggested framework described in section 3.1. Furthermore, a new modeling technique has been applied in order to capture the user features in the configuration model—the tool is described in section 3.2.

Additionally, the case study method has been chosen to analyze the proposed methods [20]. This is one of the most compelling operation management and information systems research methods [3; 34].

Moreover, structured interviews have been carried out with the relevant stakeholders to define the requirements. Subsequently, the configurator porotype has been tested on a continuous basis through workshops with the user. Hence, the model has been gradually updated from low-fidelity to high-fidelity prototypes.

## 3.1 UCD Framework

In this section, we present a comprehensive user-centered scheme to design and model configurators. We aim to give particular attention to two the following declarations:

*(i)* *Customer ∈ Configurator User*
The user of the configurator can be the customer. However, the configurator user can also be another stakeholder, for example, a salesperson or a technician.

*(ii)* *(Deliverable = Configurator) ∧ [Deliverable ≠ (product ∨ service ∨ process)]*
In Configurators UCD, the user is the configurator user. Therefore, the ultimate product, service, or process to be developed is not the configured item but the configurator.

Under these premises, we propose the following framework for User-Centered design in Configuration systems.

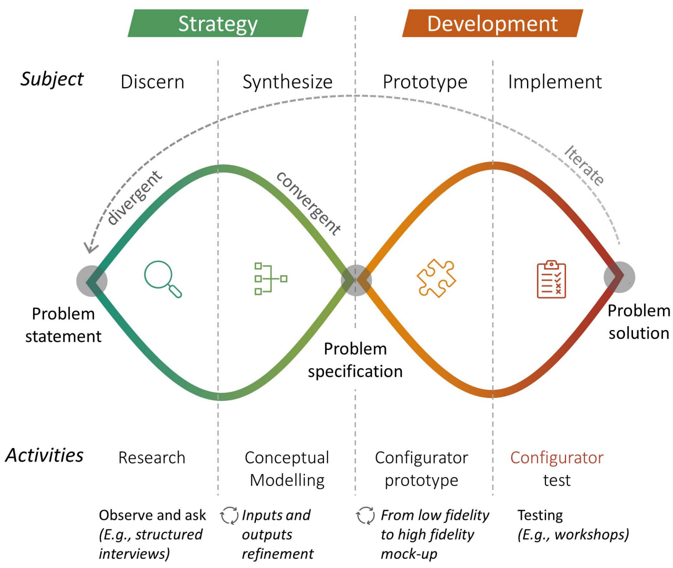


**Figure 3.** UCD Framework for developing configuration systems projects. Adapted from [4].

The purpose the framework is the development of configurators that are technologically viable and economically feasible while advantageous for the user. It adheres to the design thinking ideology which leads to innovation through four distinct stages based on the double-diamond design thinking process. We group the first two stages into, first, a *strategy phase* representing the understanding and definition of the UCD problem and, secondly, a *development phase* including creating, designing, and testing the configurator.

The first stage comprises a divergent research process in which the goal is to explore and gather information about the problem. Besides portraying the product's portfolio and characterizing the customer, it is crucial to understand and empathize with the configurator user. To comprehend the user, we need to observe the current process and question it, for example, through structured interviews.

The second stage intends to scope the problem under a convergent thinking development and represent the knowledge subset. A conceptual model helps to reflect the outcomes in which, from the UCD perspective, the most important is to depict the relationship of the attributes with the user (see section 3.2).

Third, the configurator proposals are represented through prototypes. The prototype modeling techniques vary depending on the maturity of the project development. Hence, in the early project phases, low fidelity models are developed through rapid prototyping tools such as sketches and wireframe layout representations. This will enable us to receive the user comments quickly and perform faster feedback loops. Later, high-fidelity prototypes presenting the final configurator layout can be used to test with the user mockups resembling the final configurator.

Finally, the mentioned prototypes need to be tested to determine what succeeds and what needs to be reconsidered. It is critical to test the configurator with the user and get feedback, e.g., through planned workshops.

It is worth mentioning that this is not a linear process but essentially an iterative process that intends to consider the configurator user during the configuration system development actively.

## 3.2 User-centered conceptual model

It has been stated that the currently available knowledge models do not consider a user-centered description of the configurator information. To work with the suggested UCD framework, we have adapted the so-called PVM model to represent the knowledge from the user perspective. We have chosen the PVM model as it is an ontological model that, depending on the project maturity, can be used as a conceptual model or an information model, and hence, it can reflect the progress of the UCD development. Besides, the suggested adoption of a user view could also be applied to other models.

The features are represented on the knowledge model using characterizing the attributes as positive (+) if there depict attributes dependent on the user input and as negative (-) if they are hidden attributes or "only readable" for the configurator user.

Moreover, attributes can have a predefined default value indicated with a tile grapheme (~).

This attribute characterization allows the configurator expert to keep traceability on the user-oriented knowledge model and portray and analyze the project prospects. Besides, determining the default attribute values as the most common choice done by users contributes to a smoother configuration and, on the other hand, can lead to enabling different user interfaces.

For example, in the configuration of a product, we might want to enable two configuration options: (i) simple and agile to get an approximate price or (ii) in detail and investing more time in order to get a definitive price quote. These different scenarios can be reflected through the presented tool, typifying the attributes according to the standard user features.

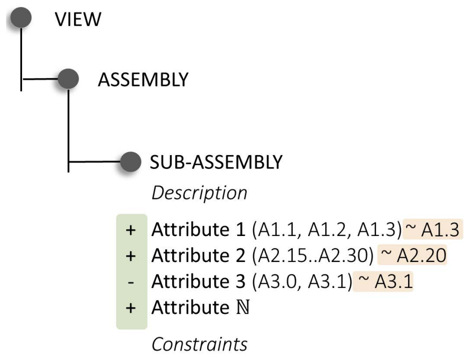


**Figure 4.** Adjustment of the PVM model to reflect user features. Adapted from [12].

# 4 CASE STUDY

The company is an Engineer-To-Order construction business that provides customized house solutions based on standard construction products and processes. The company has broad experience working with configuration systems, particularly sales configurators. It has a consolidated online web-based configurator that provides users with a customizable 3D model of the house they are designing. In the end, the user—in this case, the potential customer —is given a choices summary and a price estimation.

Besides, the company has a primitive product configurator to generate the final quotation with a fixed price and the BoM with the list of materials necessary to build the house. The product configurator and the sales configurator are not coupled since the sales configurator's outputs are redefined by external stakeholders. Hence, the final house drawings are generated after the sales configuration and serve as an input for the product configurator used by a technician.

## 4.1 Remodeling the product configurator

As stated previously, the product configurator is elementary and cannot efficiently handle the flexibility of such highly engineered products. The company wants to optimize the benefits of the product configurator by improving different specification processes' performance. In particular, the company is eager to:

(i) reduce the user's time on creating the BoM and quotation specifications by 75%;

(ii) minimizing the potential errors during the configuration process,

(iii) and, enable two different user interfaces: First, an interface that enables an agile configuration and can rapidly provide an approximate price, and, secondly, a detailed interface configuration that can generate a precise price quote.

The points above are strictly related to the configurator user, which in this case is a technician. In this context, it is essential to state that the user's expertise level on the house elements is medium to low. Consequently, the drawings represent the primary source of inputs for the configurator. Such drawings have a high degree of detail and can provide all the necessary information to set up the specifications. However, not all the data available is to be used as an input. This has been identified as one of the biggest detriments in the current configuration due to the unnecessary properties asked to the user.

In table 1, we can see the current relation matrix between the inputs from the user—measurements from the drawings—to generates the specifications. This table only represents a small fragment of 3 out of 24 modules that comprise the house: the external walls, the inner walls, and the slab foundation.

**Table 1.** Relation Matrix: Measurement-Building Part

| Measurement | External walls | Inner walls | Slab foundation |
|---|---|---|---|
| Building Area | | | x |
| Habitable Area | | x | |
| Outer Perimeter | x | | x |
| Inner Perimeter | x | | |
| Nr. Inner Corners | | | x |
| Nr. Outer Corners | | | x |

On the current configurator, all the measures are defined individually directly from information provided from the drawings. A summary of the user performance to computerize the data into the configurator is presented in Table 2 and illustrated in Figure 4. The drawing parameters are highlighted in italics.

**Table 2.** Manual computation of measurements

| Measurement | Manual Definition |
|---|---|
| Building Area | Sum of calculated areas through (A) ℕ *external walls length*. |
| Habitable Area | Sum of (B) ℕ *room area*. |
| Outer Perimeter | Sum of (A) ℕ *external walls length.* |
| Inner Perimeter | Sum of (A) ℕ *external walls length* disregarding (C) *wall width.* |
| No. Inner Corners | Visual sum of (D) *inner corners*. |
| No. Outer Corners | Visual sum of (E) *outer corners*. |

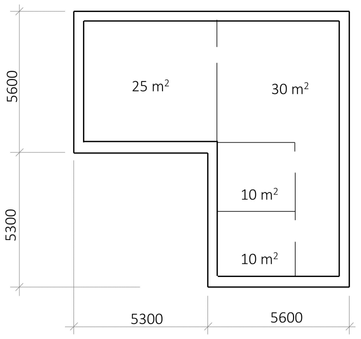


**Figure 5.** Floorplan example reflecting the available information

Additionally, from the product conceptual modeling perspective, the company has vast experience working with the so-called PVM methodology. Thus, the stakeholders are familiar with the model, and the tool learning period is abbreviated.

# 5 RESULTS

This section introduces and discusses the results of the case study concerning the RQs. Within the first section, we focus on answering RQ 1 by analyzing the use of a user-centered framework to develop configuration systems. On the other hand, in section 2, we evaluate capturing that knowledge in the configurator´s conceptual model to address RQ 2.

## 5.1 UCD in configuration system' projects

To facilitate understanding of the results obtained from using the suggested UCD, we have presented the advantages achieved in the process on each step in table 3 (refer to figure 3).

**Table 3.** Benefits of using the suggested UCD framework on the configuration process development

| Stage | Results and benefits |
|---|---|
| Step 1 | The number of needed iterations due to users' assessment is reduced as the user is actively considered throughout the process.<br>Greater insight on the project scope is given by empathizing with the user from the early development stages.<br>A better comprehension of user features due to observation and interviews with users.<br>A better understanding of UI requirements already in the initial stages of the project is achieved. |
| Step 2 | User features are captured on the configuration model facilitating the communication with the user, enabling the traceability of user features, and facilitating the description of different user interfaces.<br>The number of necessary inputs from the user can be evaluated more efficiently to reduce the interdependency of attributes. It makes the model more robust, contributing to simplify rules and constraints, which, in turn, avoids potential errors. |
| Step 3 | The time spent on prototyping is reduced, and communication improves as models are designed from low fidelity (simpler) to high fidelity (detailed) according to the project's maturity. |
| Step 4 | The recreation of usage scenarios on the workshop allows identifying missing design specifications that could be neglected. |

Moreover, we also evaluated the configurator enhancement in connection to the project goals. The most significant results are:

(i) A wider configurator acceptance and its use promotion are achieved due to the user's involvement during the development process. Hence, we can prevent potential reluctant users through the adoption of a UCD development.

(ii) The time spent configuring a product and generating a quote and BoM document is reduced from 4 hours to 1 hour for detailed configuration and to 30 minutes for basic configuration. Since it is an ongoing project, it is expected that the time spent can be further shortened. Moreover, the user's familiarization with the tool could also lower these results.

(iii) Potential wrong choices are avoided. The users are not in doubt during the configuration since they are familiar with the tool due to their involvement in the configuration development, especially on the UI design.

(iv) Targeted user interfaces are enabled in accordance with the required outputs. Thus, a “basic configuration” and a “detailed configuration” interface can be provided with the same product configurator.

## 5.2 UCD portrayed in the configuration model

The progress accomplished on step 2 was supported by mapping the user features on the configuration model. We present the results by comparing computerized attributes before using the tool (Table 2) and after utilizing the suggested UCD approach (Table 4).

**Table 4.** Automated computation of measurements

| Measurement | Automated Definition |
|---|---|
| Building Area | (A) ℕ *external walls length* (B) ℕ *external wall direction* |
| Habitable Area | (A) ℕ *external wall length* (C) *wall width.* |
| Outer Perimeter | (A) ℕ *external walls length* |
| Inner Perimeter | (A) ℕ *external wall length* (C) *wall width.* |
| Nr. Inner Corners | (B) ℕ *external wall direction* |
| Nr. Outer Corners | (B) ℕ *external wall direction* |

It is possible to observe a reduction in the number of variables from ℕA, ℕB, C, D, and E, to ℕA, ℕB, and C. This directly affected the time spent by the user configuring the product, thus minimizing the risk of possible wrong inputs. On the other hand, decreasing the number of variables enhanced the model robustness since the number of variables’ dependency was significantly decreased. Furthermore, this translated into improving the model complexity by having fewer attributes and constraints.

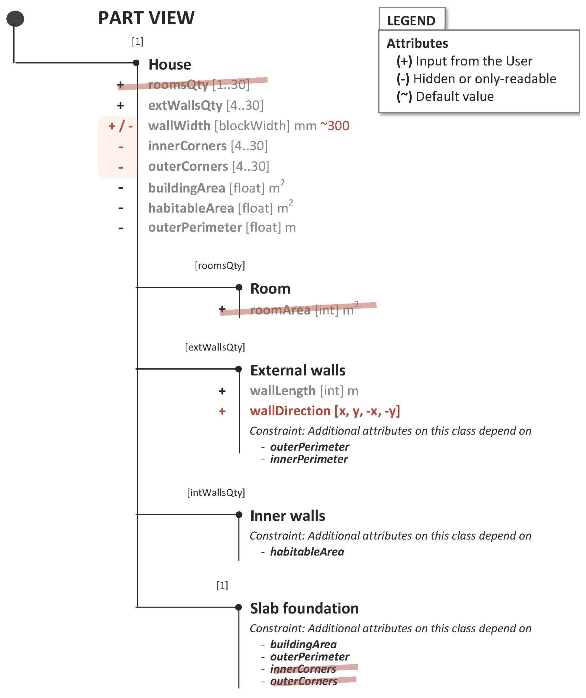


**Figure 6**. Case sample example of the user-centered conceptual model with the progression highlighted in red.

Besides, mapping the user features into the model helped monitor and record the changes executed over the user features.

Finally, using default values and their positive/negative characterization helped us describe two different user interfaces. For example, the *wallWidth* was predefined to a value of “300 mm”. This helped streamline the *detailed configuration* where the attribute is visible to the user (+) since this is the most common choice. On the other hand, given that “300 mm” is the data set mode and has a relatively low impact on the *basic configuration* desired output—an approximate price—, we set the attribute as hidden (-) to speed the configuration process.

The case sample example is presented in Figure 6 with the improvements mentioned above—from table 2 to table 4—highlighted in red.

## 6 DISCUSSION AND CONCLUSIONS

This research introduces a UCD approach to develop configuration systems supported by a tool to portray the user features on the configuration model.To this end, we stress the difference between the configurator user and the customer; and we focus on the configurator as the core artifact to be innovated instead of the configurable product, service, or process.

Through a case study, we demonstrated that empathizing with the user from the early stages of the configuration project development has a substantial positive impact on the configuration model itself and improves the user perception of the configurator.

Besides, the UX practices reflected in the conceptual modeling assist in scoping the UI requirements. It enables the reduction of dependency and the number of inputted attributes and creates a more robust design. On the other hand, the outputs from the configurator become more accurate as potentially wrong decisions are prevented due to the active involvement of the user during the complete configurator design. Moreover, the time spent by the user performing a configuration is significantly reduced since the UI has been deliberately targeted, additionally enabling different user interfaces.

Furthermore, it should also be considered the effect of the suggested method adoption over the overall project development. It is expected that using this method can extend the duration of the first iterations due to the consideration of new factors. However, it compensates for later phases of the project since fewer adjustments are required.

Finally, it is worth mentioning that the research was developed and carried out to address complex and highly engineered products. However, accommodating this methodology to develop other project configurator typology could reveal further advantages that have not been identified in this paper.

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