# Product Configurator Self-Adapting to Different Levels of Customer Knowledge

**Igor Fürstner, Zoran Anišić**

Subotica Tech – College of Applied Studies
Marka Oreškovića 16, Subotica, Serbia
ifurst@vts.su.ac.rs; azoran@vts.su.ac.rs

**Márta Takács**

Óbuda University
Bécsi út 96/B, H-1034 Budapest, Hungary
takacs.marta@nik.uni-obuda.hu

*Abstract: When selling a customized product with the support of a product configurator, there is a risk that customers will abort the configuration process if the configuration dialogue does not suit the customer well. To reduce this risk, a product configurator that self-adapts to different levels of customer knowledge instead of vice versa is needed. In this paper, a self-adapting approach for product configurators is proposed, one which relies on a fuzzy logic-based algorithm. The approach is implemented for the configuration of the thermal insulation of buildings. The product configurator is tested by users with different capabilities and a comparison of results with professionally performed calculations is performed. It is shown that the proposed approach allows inexperienced customers, too, to make appropriate decisions about thermal insulation. This is an advancement that can considerably expand the scope of the application of product configurators.*

*Keywords: mass customization; customer profiling; decision support systems; thermal insulation; fuzzy logic*

## 1 Introduction

Nowadays, customers expect to get exactly what they would like. Therefore products should be customized, i.e. mass customized, which results in a drastic increase in the product variety offered by enterprises [1], [2]. This changes the role of the customer from being the consumer of a product to being an active partner in a process of adding value. Active customer participation is crucial for the successful incorporation of customer needs into the product, which directly influences the final product offering [3], [4], [5].

Recent developments in product configuration systems support the process of customized product development and production [6], [7], [7], [9]. Product configurators involve the customer into the configuration process. This raises several issues that need to be addressed: one of these is that despite the fact that nowadays customers are knowledgeable in general, they are still far from being experts that can really co-create a product or a service [10]. Customers usually only want the product alternatives that exactly meet their requirements; if too much of a choice is offered or an offer is too complex, customers can feel frustrated or confused, and therefore incapable of making proper decisions. This can lead to the abortion of the configuration process [1], [11]. This overload of information is caused by the limited information processing capacity of humans, the lack of customer knowledge about the product, and customer ignorance about his or her real individual needs [12].

In order to reduce the probability of the customer aborting the configuration process, some authors suggest the use of different types of configuration dialogues that are adapted to different types of customers [1]. Unfortunately, these authors do not provide any indication whether the assignment of the dialogue type to a customer is chosen by the customer or defined by the system.

The present paper contributes to fill this gap by developing a configuration approach where the configurator self-adapts to the customer's expertise in a given area and provides a successful product configuration, while maintaining the necessary level of detail and results accuracy. The approach is tested on a real product configurator for the outer thermal insulation of individual residential buildings (not a block of flats) which is an area of importance involving private building owners without expertise, installers with great experience but limited theoretical knowledge, and experts with a great amount of experience and knowledge.

# 2 Theoretical Background

The theoretical basis of the present work, on the one hand, is the design of configuration dialogues and on the other hand includes the principles of thermal insulation. Even though the aim is to contribute to the design of adapted configuration dialogues, one needs to be familiar with the theoretical bases of thermal insulation to appreciate the proposed application. This blend of different fields is a common characteristic of applied research on product configuration. For the sake of clarity, the two fields involved will be discussed separately.

## 2.1 Product Configuration and Choice Complexity Experienced by Customer

The identification and implementation of customer requirements are significant issues for successful product development [13] as well as for product configuration [1]. To be able to select or filter objects for an individual, information is required about the individual. Such information is also necessary to be able to decide which options to present and how to present them. For example, performance-oriented language can be used for non-expert customers while components-oriented language can be used for highly interested and experienced customers [1], [14]. The problem of adapting the configuration process to different customers can be addressed with the identification of different customer profiles that group individual customers based on some crucial characteristics such as the knowledge about the product. Based on the defined customer profiles, different descriptions of the same product can and should be provided.

Customer profiles consist of general, specific and contextual information about customers. General information usually deals with basic and demographic attributes, information about general interests, information about relationships to other customers, information about purchase history and usage/interaction behaviour and ratings of products, product components and certain attributes [15], [16]. Specific information refers to the specific requirements of the customer [17], while contextual information about customers is information such as the time of the day, the date, etc. [18].

In order to define an exact customer profile for each individual customer, a proper customer profile definition model has to be developed. Today IT technology makes it possible to collect information from customers implicitly or explicitly. Customer profiles can be obtained from the customers' purchase history [19], [20]. They can also be created by specifying information explicitly at the beginning of the configuration process. Also, customer behaviour during the configuration process is used to profile the customer [21], [22]. Besides this, information on behaviour of other customers that have similarities to the given customer is also used to define the customer [23]. Even though many customer profile models have been suggested in the literature, there is no specific discussion about customer profile definition in the field of outer thermal insulation of buildings.

## 2.2 The Configuration of Outer Thermal Insulation

In recent years, we have witnessed the fact that energy resource prices have risen considerably. In addition, environmental issues have become more relevant than ever before [24]. The Directive 2002/91/EC and 2010/31/EU of the European Parliament and Council on the energy performance of buildings, which can be universally taken into account as recommendations beyond the borders of the European Union, state among other things that since buildings account for 40% of total energy consumption in the Union, and since the sector is expanding, energy consumption is growing. Therefore, reduction of energy consumption in the construction sector constitutes important measures needed to reduce energy dependency and greenhouse gas emissions.

Therefore, the outer thermal insulation of buildings is becoming more and more important. The most favourable insulation must be calculated based on a particular lifetime for the building [25], [26]. If the structure has been correctly designed, there will be nothing to affect the insulation when it is in place. Insulation makes good economic sense as it reduces energy consumption in buildings. Insulation as a single investment pays for itself many times over during the life cycle of a building [27], [28]. A high insulation standard for floors, walls, roof and windows does not only mean lower energy consumption. It will also reduce the power need and makes the heating period shorter [29]. It improves the conservation of existing free energy and creates conditions for simpler heating systems [30].

Research in the field of outer thermal insulation defines several rules that have to be considered when one wants to make the necessary calculations regarding thermal, ventilation, solar and other losses or gains. Those rules require knowledge about different parameters, such as the overall position of the building, the building's characteristics (structure, measures, materials, etc.), and the conditions regarding the surroundings (weather data, etc.) in order to be able to calculate the required level of thermal insulation [31]. On a professional level, i.e. if one wants to have highly accurate results, these calculations include all required information in detail and will not be discussed in this paper, because several professional software packages exist on the market that deal with the problem, such as *Bausoft Winwatt, Resfen, CASAnova,* etc.

Nowadays, a number of different product configurators are used to configure various types of products, yet in the field of outer thermal insulation of buildings, there is not any product configurator that can satisfy the requirements of different users. Existing literature does not discuss any calculation methods that can provide acceptable results if just a fraction of required information is available, which is the case of customers who are not professionals in the field of thermal insulation.

# 3 Objective and Method

## 3.1 Objective

The paper aims at contributing to fill a gap in literature by introducing the necessary elements with which a successful product configurator in the field of thermal insulation of individual residential buildings can be created and implemented. Thus, a product configuration approach is proposed that self-adapts to the individual capabilities of the given customer, where these may range from having no knowledge about thermal insulation at all to being professionals in the related field.

## 3.2 Method

In order to propose and test the self-adapting configuration approach for thermal insulation, the authors have integrated their knowledge gained from literature on customer profile definition and thermal insulation with an analysis of various product configurators on the web, and with the specific experience of a company that produces thermal insulation materials. The authors' years of personal field experience on the topic have been another important element in making feasible decisions.

The development process has involved several cycles of refinement in the algorithm and the entire product configurator. At each cycle, first the algorithm for customer profiling was discussed. Subsequently, the quantity and the required level of details regarding input parameters, constraints and calculations to obtain the desired insulation results were specified. Each cycle was then concluded with a number of trials by asking some volunteers to act as test persons. Feedback was always required from the test subjects until finally no significant new insights were obtained.

Once the profiling algorithm and the configuration procedure were established, a test was performed in order to evaluate the results. The test was performed by two groups of potential users. For one group, it was assumed that they had some technical knowledge in the related field, while for the other groups this was not the case. The first group was comprised of 27 university students of mechanical engineering who either had to work with insulation issues at their home, during summer work or due to specific examinations at the university. The second group was made up of 26 university students who up to that point had not had any kind of experience in this field, but were expected to attain some in the future. The results of the configurations were compared to exact calculations performed by the authors.

# 4 Customer Profile Definition

The need for various customer profiles is based on the experience of using a previous version of the developed configurator for outer thermal insulation of buildings [32]. The configurator was meant to be used by customers with technical knowledge ranging from the almost non-existent to professional but without the differentiation in the configuration dialogue. The results of its use showed that most of the problems arose because some of the previous non-professional customers had found the product configurator too complex to use and did not finish the configuration process. On the other hand, some of the professional customers found that the configurator lacked the possibility of defining exact and precise input parameters. Other problems included the lack of variance in the degree of result accuracy and the duration of the configuration process. This need led to the introduction of a product configuration procedure shown in Fig. 1.

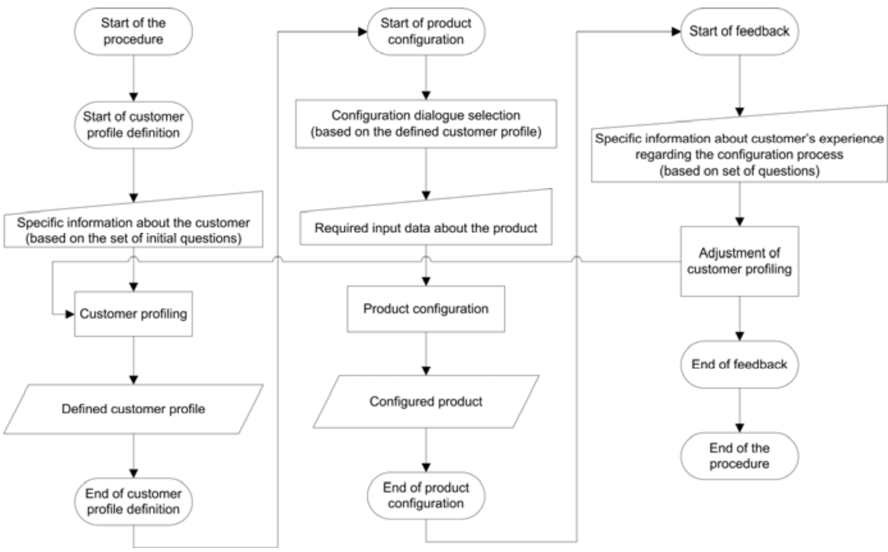


Figure 1

The product configuration procedure

## 4.1 Overview of Customer Profile Definition

As an answer to observed problems, three types of customer profiles have been introduced: *beginner*, *intermediate* and *professional*. The "*beginner customer*" is a customer without proper technical knowledge about thermal insulation, or maybe a customer with no need for highly accurate results, or a customer with a need of a fast enough result, etc. The "*intermediate customer*" is a customer with average technical knowledge about thermal insulation, but it can also be a customer without proper technical knowledge about thermal insulation but with more time for completing the configuration process or with a need for more accurate result, etc. The "*professional customer*" is a customer with great knowledge about the problem of thermal insulation; it may also be a customer with general technical knowledge about thermal insulation but with more time for completing the configuration process or with a need for more accurate result, etc.

In order to define the appropriate customer profile, an algorithm for collecting and using specific information about customers is introduced. The customer is given a set of initial questions to be answered at the beginning of the configuration process. The possible answers are defined within a range of very low to very high. Along with the answers, the order of answering the questions is also taken into account, because customers usually, based on their belief, sooner answer questions that are of higher importance to them than questions that are not. There is also an option to leave unanswered a question the customer feels is unimportant [33].

To analyze the answers generated by each customer and to use them to form a customer profile, a number of different approaches may be used. Nevertheless, the linguistic nature of the questions and answers refers to the use of a non-crisp logic. This led to the use of fuzzy-based technique to make a decision about the appropriate customer profile [34], [35], [36]. The technique used is Mamdani's fuzzy inference method, which is one of the most commonly seen fuzzy methodologies. Also, after the configuration process, the customer's feedback to his/her satisfaction with the configured profile is analyzed and the algorithm for customer profile definition in the future is adapted according to the feedback.

All the questions asked have an associated linguistic variable for storing the answers that can have values ranging from 0 to 1. For the same answers, the $\mu(x)$ membership functions of linguistic variables may change according to the order in which they had been answered. If the answer to the question is the first one (each question is defined by a linguistic variable with different values), the membership functions taper, which is formulated as: $\mu^{1st}(x) = [\mu(x)]^{y_i}$, where $y_i \geq 1$. It results in a more unique response. If the answer to the question is the last one, the membership functions expand, i.e. the equations are changed in the same manner, but: $y_i \leq 1$. It results in a more vague response.

The fuzzy output from the system, i.e. the decision is made in a manner that for $i$ initial questions, each of which can have $y_i$ values, $y_1 * y_2 * ... * y_i$ if-then rules can be defined. The rules are designed to produce $j$ different outputs $o$ with defined membership functions. After the evaluation of if-then rules, an aggregated output is generated. The aggregated output is then defuzzified by using the centroid calculation method.

Changes in input membership functions influence the customer profile definition. For the same answers, but for a different answering order, the configured customer profile can be different.

After the configuration task is finished, the customer is asked to answer a new set of questions, where the values of the answers can range from -0.5 to 0.5. The answers to the questions are the feedback about how well the configurator has recognized the customer's needs and limitations. Initially, all the answers are set to the value of 0, which means that the customer is satisfied with the configuration process. Based on the answers to questions, the values for input linguistic variables are modified to new values as: $new\_value = previous\_value + \frac{feedback}{2}$, where: $0 \le new\_value \le 1$. This is the input for a new fuzzy output from the system, i.e. a new decision. This new output $o_{new}$ takes into consideration whether a customer is satisfied with a configured customer profile. Based on the difference between an original and a new output, the membership functions for $o_{i+1}$, where $o_{i+1}$ is the output for customer profile configuration in the future, are shifted left or right to better articulate the future customers' preferences. The amount of shifting $sa$ is calculated as: $sa = \frac{o - o_{new}}{10}$. The division by 10 is used to assure that the shift is not too big.

## 4.2 Initial Customer Profile Definition

The initial questions asked before the start of the configuration process are:

- What is your estimate of your knowledge about thermal insulation?
- What are your needs considering the accuracy of the configuration results?
- How much time do you have for completing the configuration process?

The answers can range from "I have no knowledge about thermal insulation at all" (Where the value of the answer is 0) to "I am a professional in the field of thermal insulation" (Where the value of the answer is 1) for the first question; from "I need as accurate result as possible" (Where the value of the answer is 0) to "I just want a rough estimate" (Where the value of the answer is 1) for the second question; and from "I have enough time for completing the configuration process" (Where the value of the answer is 0) to "I have limited time for completing the configuration process" (Where the value of the answer is 1) for the third question. Initially, all the answers are set to the value of 0.5. The answers are used as input data for customer profile configuration.

Based on asked questions and answers, three linguistic variables are defined:

- *Knowledge about thermal insulation k*, whose values are: very poor, poor, average, good and very good;
- *Accuracy of the configuration results a*, whose values are: high, average, low;
- *Time for the configuration process t*, whose values are: enough, average, not enough.

The membership functions for the variables are chosen based on testing and experience and are presented in equations (1)-(3).

$$\mu_{k=very\_poor}(x)=\begin{cases}1, & 0\le x\le 0.05\\ \frac{0.5-x}{0.5-0.05}, & 0.05<x\le 0.5\\ 0, & 0.5<x\le 1\end{cases}\qquad \mu_{k=poor}(x)=\begin{cases}\frac{x}{0.3}, & 0\le x\le 0.3\\ \frac{0.6-x}{0.6-0.3}, & 0.3<x\le 0.6\\ 0, & 0.6<x\le 1\end{cases}$$

$$\mu_{k=average}(x)=\begin{cases}0, & 0\le x\le 0.2\\ \frac{x-0.2}{0.5-0.2}, & 0.2<x\le 0.5\\ \frac{0.8-x}{0.8-0.5}, & 0.5<x\le 0.8\\ 0 & 0.8<x\le 1\end{cases}\qquad \mu_{k=good}(x)=\begin{cases}0, & 0\le x\le 0.4\\ \frac{x-0.4}{0.7-0.4}, & 0.4<x\le 0.7\\ \frac{1-x}{1-0.7}, & 0.7<x\le 1\end{cases}\tag{1}$$

$$\mu_{k=very\_good}(x)=\begin{cases}0, & 0\le x\le 0.5\\ \frac{x-0.5}{0.95-0.5}, & 0.5<x\le 0.95\\ 1, & 0.95<x\le 1\end{cases}$$

$$\mu_{a=high}(x)=\begin{cases}1, & 0\le x\le 0.1\\ \frac{0.75-x}{0.75-0.1}, & 0.1<x\le 0.75\\ 0, & 0.75<x\le 1\end{cases}\qquad \mu_{a=average}(x)=\begin{cases}0, & 0\le x\le 0.1\\ \frac{x-0.1}{0.5-0.1}, & 0.1<x\le 0.5\\ \frac{0.9-x}{0.9-0.5}, & 0.5<x\le 0.9\\ 0 & 0.9<x\le 1\end{cases}\tag{2}$$

$$\mu_{a=poor}(x)=\begin{cases}0, & 0\le x\le 0.25\\ \frac{x-0.25}{0.25-0.9}, & 0.25<x\le 0.9\\ 1, & 0.9<x\le 1\end{cases}$$

$$\mu_{t=enough}(x)=\begin{cases}1, & 0\le x\le 0.1\\ \frac{0.75-x}{0.75-0.1}, & 0.1<x\le 0.75\\ 0, & 0.75<x\le 1\end{cases}\qquad \mu_{t=not\_enough}(x)=\begin{cases}0, & 0\le x\le 0.25\\ \frac{x-0.25}{0.25-0.9}, & 0.25<x\le 0.9\\ 1, & 0.9<x\le 1\end{cases}\tag{3}$$

$$\mu_{t=average}(x)=\begin{cases}\frac{x-0.1}{0.5-0.1} & 0\le x\le 0.5\\ \frac{0.9-x}{0.9-0.5}, & 0.5<x\le 1\end{cases}$$

If the answer to the question is the first one, the used membership functions change in a manner described by equations (4)-(6). If the answer to the question is the last one, the membership functions change in a manner described by equations (7)-(9).

$$\begin{aligned}\mu_{k=very\_poor}{}^{1st}(x) &= \left[\mu_{k=very\_poor}(x)\right]^2 \\ \mu_{k=poor}{}^{1st}(x) &= \left[\mu_{k=poor}(x)\right]^2 \\ \mu_{k=average}{}^{1st}(x) &= \left[\mu_{k=average}(x)\right]^2\end{aligned} \qquad \begin{aligned}\mu_{k=good}{}^{1st}(x) &= \left[\mu_{k=good}(x)\right]^2 \\ \mu_{k=very\_good}{}^{1st}(x) &= \left[\mu_{k=very\_good}\right]^2\end{aligned} \tag{4}$$

$$\begin{aligned}\mu_{a=high}{}^{1st}(x) &= \left[\mu_{a=high}(x)\right]^2 \\ \mu_{a=average}{}^{1st}(x) &= \left[\mu_{a=average}(x)\right]^2\end{aligned} \qquad \mu_{a=poor}{}^{1st}(x) = \left[\mu_{a=poor}(x)\right]^2 \tag{5}$$

$$\begin{aligned}\mu_{t=enough}{}^{1st}(x) &= \left[\mu_{t=enough}(x)\right]^2 \\ \mu_{t=average}{}^{1st}(x) &= \left[\mu_{t=average}(x)\right]^2\end{aligned} \qquad \mu_{t=not\_enough}{}^{1st}(x) = \left[\mu_{t=not\_enough}(x)\right]^2 \tag{6}$$

$$\begin{aligned}\mu_{k=very\_poor}{}^{1st}(x) &= \left[\mu_{k=very\_poor}(x)\right]^{0.9} \\ \mu_{k=poor}{}^{1st}(x) &= \left[\mu_{k=poor}(x)\right]^{0.75} \\ \mu_{k=average}{}^{1st}(x) &= \left[\mu_{k=average}(x)\right]^{0.25}\end{aligned} \qquad \begin{aligned}\mu_{k=good}{}^{1st}(x) &= \left[\mu_{k=good}(x)\right]^{0.75} \\ \mu_{k=very\_good}{}^{1st}(x) &= \left[\mu_{k=very\_good}\right]^{0.9}\end{aligned} \tag{7}$$

$$\begin{aligned}\mu_{a=high}{}^{last}(x) &= \left[\mu_{a=high}(x)\right]^{0.25} \\ \mu_{a=average}{}^{last}(x) &= \left[\mu_{a=average}(x)\right]^{0.75}\end{aligned} \qquad \mu_{a=poor}{}^{last}(x) = \left[\mu_{a=poor}(x)\right]^{0.25} \tag{8}$$

$$\begin{aligned}\mu_{t=enough}{}^{last}(x) &= \left[\mu_{t=enough}(x)\right]^{0.25} \\ \mu_{t=average}{}^{last}(x) &= \left[\mu_{t=average}(x)\right]^{0.75}\end{aligned} \qquad \mu_{t=not\_enough}{}^{last}(x) = \left[\mu_{t=not\_enough}(x)\right]^{0.25} \tag{9}$$

The fuzzy output from the system is designed to produce three different outputs *o*: *beginner*, *intermediate* and *professional*. Its membership functions are defined in equation (10). The decision is made using 45 *if-then* rules that take into consideration all of the possible answers. The rules are defined as the examples given in equation (11). After the evaluation of *if-then* rules, an aggregated output is generated that maximizes the values for the membership functions to the maximum values obtained from the rules. The final output, i.e. the customer profile is determined after defuzzification.

$$\mu_{o=beginer}(x) = \begin{cases} 1, & 0 \le x \le \alpha_0 \\ \dfrac{\beta_0 - x}{\beta_0 - \alpha_0}, & \alpha_0 < x \le \beta_0 \\ 0, & \beta_0 < x \le 1 \end{cases} \qquad \mu_{o=professional}(x) = \begin{cases} 0, & 0 \le x \le \phi_0 \\ \dfrac{x - \phi_0}{\phi_0 - \varphi_0}, & \phi_0 < x \le \varphi_0 \\ 1, & \varphi_0 < x \le 1 \end{cases}$$

$$\mu_{o=intermediate}(x) = \begin{cases} 0, & 0 \le x \le \chi_0 \\ \dfrac{x - \chi_0}{\delta_0 - \chi_0}, & \chi_0 < x \le \delta_0 \\ \dfrac{\varepsilon_0 - x}{\varepsilon_0 - \delta_0}, & \delta_0 < x \le \varepsilon_0 \\ 0 & \varepsilon_0 < x \le 1 \end{cases} \qquad \begin{aligned} &\alpha_0 = 0.2, \beta_0 = 0.5 \\ &\chi_0 = 0.3, \delta_0 = 0.5 \\ &\varepsilon_0 = 0.7, \phi_0 = 0.5 \\ &\varphi_0 = 0.8 \end{aligned} \tag{10}$$

$$
\begin{aligned}
&\quad if\ (\mu_{k=very\_poor} \neq 0 \wedge \mu_{a=high} \neq 0 \wedge \mu_{t=enough} \neq 0) \Rightarrow \\
&1.\ \mu_{o=\mathrm{int}ermediate} = \min(\mu_{k=very\_poor}, \mu_{a=high}, \mu_{t=enough}) \\
&\ldots \\
&\quad if\ (\mu_{k=average} \neq 0 \wedge \mu_{a=poor} \neq 0 \wedge \mu_{t=not\_enough} \neq 0) \Rightarrow \\
&27.\ \mu_{o=beginner} = \min(\mu_{k=average}, \mu_{a=poor}, \mu_{t=not\_enough}) \\
&\ldots
\end{aligned}
\tag{11}
$$

## 4.3 Feedback

After the configuration task is finished, the customer is asked to answer a set of three new questions:

- Are you satisfied with the complexity of the configurator? *c*;
- Is the result satisfactory? *s*;
- Are you satisfied with the time spent for the configuration process? *i*.

The answers can range from "The configurator is too complex" (where the value of the answer is -0.5) to "The configurator is too easy " (where the value of the answer is 0.5) for the first question; from "The results should be more detailed and precise" (where the value of the answer is -0.5) to "The results are too detailed" (where the value of the answer is 0.5) for the second question; and from "I could have spent more time for the configuration process" (where the value of the answer is -0.5) to "The configuration process was too long" (where the value of the answer is 0.5) for the third question. Initially, all the answers are set to the value of 0, which means that the customer is satisfied with the configuration process.

Based on the answers to questions, the input values for $k,a,t$ are modified to $k_{new},a_{new},t_{new}$, as was described in *4.1 Overview of customer profile definition*. This is the input for a new fuzzy output from the system, i.e. a new decision. This new output $o_{new}$ takes into consideration whether a customer is satisfied with a configured customer profile. Based on the difference between an original and a new output, the membership functions for $o_{i+1}$ are shifted left or right to better articulate the customers' preferences in the future. The shifted membership functions for $o$ with corrections are presented in equation (12).

$$
\mu_{o=dummy}{}^{i+1}(x)=\begin{cases}1, & 0\le x\le \alpha_{i+1}=(\alpha_i+sa)\\ \dfrac{\beta_{i+1}-x}{\beta_{i+1}-\alpha_{i+1}}, & \alpha_{i+1}=(\alpha_i+sa)< x\le \beta_{i+1}=(\beta_i+sa)\\ 0, & \beta_{i+1}=(\beta_i+sa)< x\le 1\end{cases}
$$

$$
\mu_{o=\text{int}ermediate}{}^{i+1}(x)=\begin{cases}0, & 0\le x\le \chi_{i+1}=(\chi_i+sa)\\ \dfrac{x-\chi_{i+1}}{\delta_{i+1}-\chi_{i+1}}, & \chi_{i+1}=(\chi_i+sa)< x\le \delta_{i+1}=(\delta_i+sa)\\ \dfrac{\varepsilon_{i+1}-x}{\varepsilon_{i+1}-\delta_{i+1}}, & \delta_{i+1}=(\delta_i+sa)< x\le \varepsilon_{i+1}=(\varepsilon_i+sa)\\ 0 & \varepsilon_{i+1}=(\varepsilon_i+sa)< x\le 1\end{cases}
$$

$$
\mu_{o=professional}{}^{i+1}(x)=\begin{cases}0, & 0\le x\le \phi_{i+1}=(\phi_i+sa)\\ \dfrac{x-\phi_{i+1}}{\phi_{i+1}-\varphi_{i+1}}, & \phi_{i+1}=(\phi_i+sa)< x\le \varphi_{i+1}=(\varphi_i+sa)\\ 1, & \varphi_{i+1}=(\varphi_i+sa)< x\le 1\end{cases}
\qquad (12)
$$

$$
\begin{aligned}
&if\alpha_{i+1}<0.05then\alpha_{i+1}=0.05\\
&if\alpha_{i+1}>0.35then\alpha_{i+1}=0.35\\
&if\beta_{i+1}<0.35then\beta_{i+1}=0.35\\
&if\beta_{i+1}>0.65then\beta_{i+1}=0.65\\
&if\chi_{i+1}<0.15then\chi_{i+1}=0.15\\
&if\chi_{i+1}>0.45then\chi_{i+1}=0.45\\
&if\delta_{i+1}<0.35then\delta_{i+1}=0.35\\
&if\delta_{i+1}>0.65then\delta_{i+1}=0.65\\
&if\varepsilon_{i+1}<0.55then\varepsilon_{i+1}=0.55\\
&if\varepsilon_{i+1}>0.85then\varepsilon_{i+1}=0.85\\
&if\phi_{i+1}<0.35then\phi_{i+1}=0.35\\
&if\phi_{i+1}>0.65then\phi_{i+1}=0.65\\
&if\varphi_{i+1}<0.65then\varphi_{i+1}=0.65\\
&if\varphi_{i+1}>0.95then\varphi_{i+1}=0.95
\end{aligned}
$$

# 5 Configuration of Thermal Insulation

Different customer profiles ask for different levels and complexity of input parameters and constraints. Due to extensive amount of data and required calculations, this chapter presents just a brief overview of required input parameters, calculations and results that are shown in Fig. 2.

# 6 Experiment

The developed configurator was tested to obtain results regarding the accuracy of the calculated heat losses, configured thermal insulation and the necessary time for the configuration process. To be able to assess the quality of the configured results, exact calculations using professional software were performed by the authors.

The configuration process was carried out by two groups of potential customers, with differently assumed capabilities regarding their knowledge on thermal insulation. All participants of the experiment tested the configurator individually. In the initial phase of the configuration process, for each participant a customer profile was defined based on input questions. The customer sample and the result of customer profiling is presented in Table 1. Differences in assumed and profiled customers resulted mostly because some of the participants assumed to have no related knowledge at all asked for results of higher accuracy and/or declared themselves to have more time available. At the same time, some of the participants assumed to have proper capabilities asked for short configuration process or had no need for accurate results.

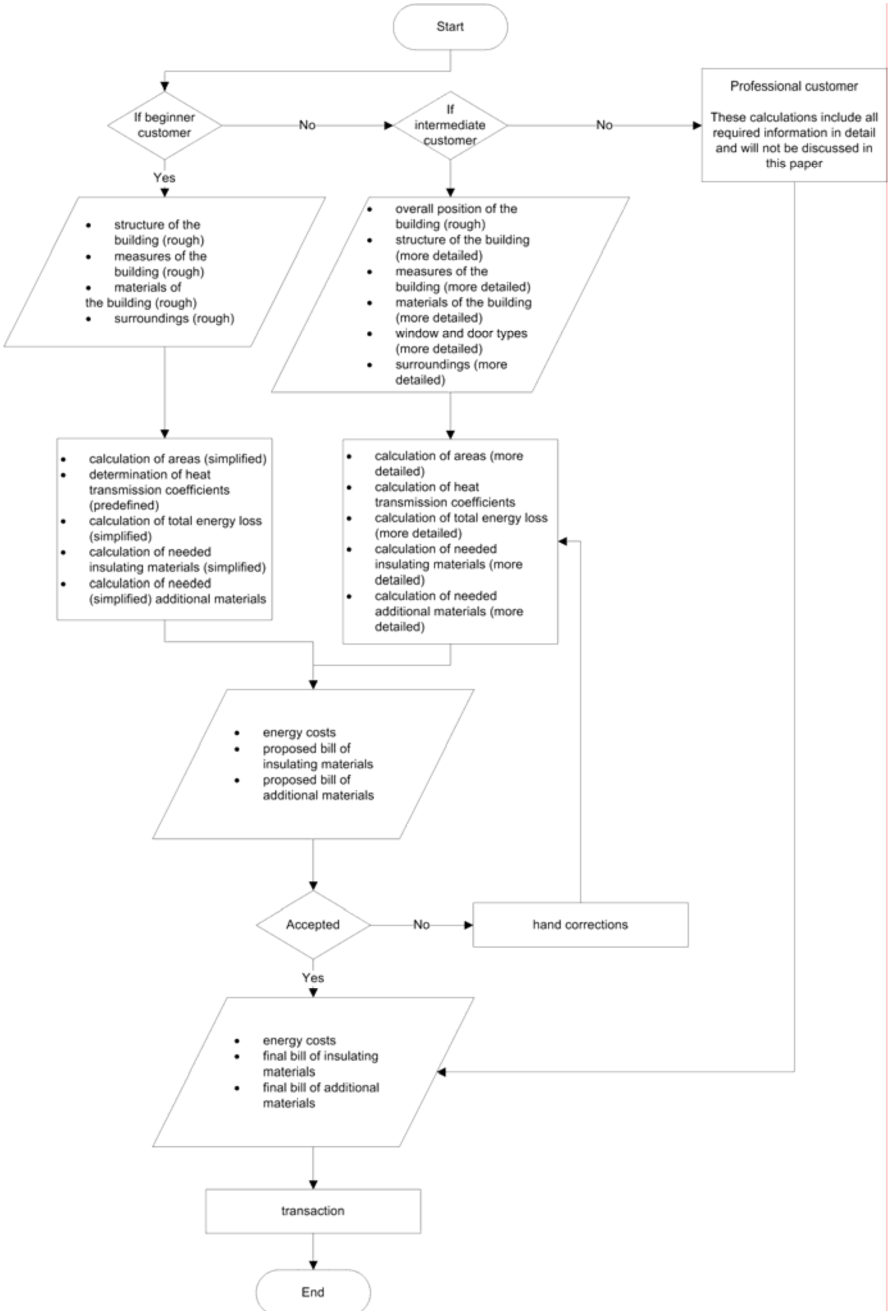


Figure 2

Simplified calculation algorithm

Table 1
The customer sample and the result of customer profiling

| Participant characteristics (defined before customer profiling) | | Participant profiles (resulting after customer profiling) | |
|---|---|---|---|
| | | Profiled as *beginner customer* | Profiled as *Intermediate customer* |
| Assumed to have some technical knowledge | 27 | 5 | 22 |
| Assumed to have no technical knowledge | 26 | 19 | 7 |

Based on the defined customer profile, each participant configured the outer thermal insulation for five different individual residential buildings that were common in design in the region of Central and East Europe and available for measurement. An example of input data regarding two types of buildings in the case of beginner and intermediate customer is presented in Appendix A. The necessary data used in the case of the professional customer is obtained from construction documentation of the buildings and is not presented in the paper.

Heat loss is calculated for following input temperatures [31]:

- Outer average air temperature - $268[K]$;
- Average ground temperature - $285[K]$;
- Average air temperature of the cellar - $285[K]$;
- The building's inner average air temperature - $293[K]$;
- Unused average air temperature of the loft - $268[K]$.

Calculated average heat losses without insulation and with the proposed insulation, as well as average relative deviations of calculated heat losses without insulation and with the proposed insulation from the exact calculations for different customer profiles, are shown in Table 2.

The result of the configuration process is the bill of necessary insulating and additional materials for the configured insulation. An example of one calculated bill of insulating and additional materials for the second type of analyzed buildings is shown in Appendix B.

# 7 Discussion of Results

The developed product configurator is to be used by a wide range of customers, those with average or no technical knowledge at all, as well as those who are professionals in the related field. Based on the customer profile selected by the configurator by interacting with the customer, the product configurator provides different results and satisfies different objectives regarding the complexity of the dialogue, the time required by the configuration process and the accuracy of the obtained results i.e. the resulting configurations.

Table 2

Average calculated heat losses [kWh/month] and relative deviations to detailed calculations

| **Building** | **Without insulation** | | | **With proposed insulation** | | |
|---|---|---|---|---|---|---|
| | **Type of customer** | | | **Type of customer** | | |
| | **Beginner** | **Intermediate** | **Professional** | **Beginner** | **Intermediate** | **Professional** |
| No. 1 (Detached building, "square" shaped ground plan, no cellar, one floor, brick wall, etc.) | 11380 | 12165 | 12560 | 5340 | 3684 | 3964 |
| | *-9.39%* | *-3.14%* | *0%* | *34.71%* | *-7.06%* | *0%* |
| No. 2 (Detached building, "T" shaped ground plan, cellar, two floors with loft, brick wall with plaster, etc.) | 17456 | 21165 | 20560 | 8465 | 5830 | 6156 |
| | *-15.10%* | *2.94%* | *0%* | *37.51%* | *-5.30%* | *0%* |
| No. 3 (In contact with another building, "L" shaped ground plan, cellar, one floor with loft, brick wall, etc.) | 6087 | 5179 | 5347 | 1236 | 1125 | 1034 |
| | *13.84%* | *-3.14%* | *0%* | *19.54%* | *8.80%* | *0%* |
| No. 4 (In contact with another building, "square" shaped ground plan, no cellar, one floor, brick wall with plaster, etc.) | 7891 | 7773 | 7650 | 1956 | 2236 | 2123 |
| | *3.15%* | *1.61%* | *0%* | *-7.87%* | *5.32%* | *0%* |
| No. 5 (In contact with another building, "C" shaped ground plan, no cellar, one floor, brick wall, etc.) | 8035 | 7435 | 7095 | 5203 | 4620 | 4205 |
| | *13.25%* | *4.79%* | *0%* | *23.73%* | *9.87%* | *0%* |

The results for the “*beginner customer*” show that absolute average deviation from the exact calculations of heat losses ranges from 3.15% to 15.10% for calculations without thermal insulation and from 7.87% to 37.51% for calculations with thermal insulation (Table 2). The deviation from the detailed calculations regarding the calculated amounts of the required insulating and additional materials is up to 100% for some materials (Appendix B). The necessary time for the configuration process is about 3-5 minutes. The required number of input data is 11. The number and type of input data indicates that customers without proper technical knowledge can input the data successfully and in a relatively short time. This fulfills one of the objectives of the research in terms of the usability for non-professional customers. However, input data limits the possibilities of obtaining highly accurate results because, compared with the detailed calculations, the calculation algorithm needs to be considerably simplified (Fig. 2). The simplification of the calculation procedure leads to results, both of the calculations of heat losses and the required materials, which cannot be acceptable in a technical sense, though these results will lend useful insight into the needs, purpose and required level of thermal insulation. Keeping in mind the definition of the beginner customer, the objective of providing acceptable accuracy is also fulfilled.

The results for the "*intermediate customer*" show that the absolute average deviation from the exact calculations of heat losses ranges on the one hand from 1.61% to 4.79% for calculations without thermal insulation and on the other hand from 5.30% to 9.87% for calculations with thermal insulation (Table 2). The deviation of the calculated amounts of the necessary insulating and additional materials is up to 6% (Appendix B). It must be pointed out that on this level all of the required insulating and additional insulating materials are included in the result. The time required for the configuration process amounts to approximately 6-12 minutes. At this level the required number of input data varies due to the differences that appear in the structure of the analyzed buildings. The number of input data range from proximately 60 to more than a 100 if the building consists of several floors or has a more complex ground plan (Appendix A). This indicates that the configuration task is extensive; however, the type of data and the fact that many data are inherited based on previous input will ensure that the configuration task will take low cognitive effort and a relatively short time. The input data enable the definition of a more complex calculation algorithm (Fig. 2) that provides results acceptable in a technical sense. It must be mentioned that when purchasing materials in practice, it is usually recommended to buy quantities that are 5-10% larger due to waste occurring in the process of applying the insulation. Given the definition of the "*intermediate customer*", objectives regarding complexity and cognitive effort are fulfilled.

Based on input data, the obtained model of the building for the beginner and intermediate customer differs to greater or lesser extent from the actual ground plan shape, structure and dimensions of an original building. These differences lead to calculation results that may have higher or lower results compared to detailed calculations (Table 2). Therefore deviations of results compared to detailed calculations may in some cases be negative, and in other cases positive values. For the same building, the configuration of the beginner customer can yield a result that is for instance lower than that of detailed calculation, while at the same time the case of the intermediate customer can have higher calculated values. The reason for this occurrence lies in the fact that the calculation algorithms in these two cases are different.

The results for the "*professional customer*" are of high accuracy, yet this also means that the calculation algorithm is rather complex and requires an extensive amount of data both specific and typical for the area of investigations. Therefore, the necessary time for the whole process is several times longer than on the previously described levels and it may take up to several hours if the analyzed building has a more complex structure. While the results for this level will be more precise, they also require expert technical knowledge on thermal insulation from the customer. This, on the other hand, may also mean that this type of calculation is no longer considered a configuration in the classical sense of the term (which takes place in the sales process), but a full-scale calculation process (which takes the form of a professional service that should be paid for).

## Conclusions

The aim of this research has been to develop and test a product configuration approach that can self-adapt to customers who have different levels of knowledge related to the configured products as well as their own real individual needs. In order to be able to develop a product configurator for such a wide range of customers and to avoid the abortion of the configuration process, and thus of the final economic transaction, three customer profiles have been identified: *beginner*, *intermediate* and *professional*. In order to map the customer onto one of these profiles, an algorithm has been proposed that uses specific information about customers and their behaviour during the profile definition process. For each customer profile a different configuration dialogue has been defined so that the amount and complexity of input information decreases in lower customer profiles. To manage the differences of input data, an associated calculation algorithm has been developed for each of the identified customer profiles.

To evaluate the performance of the proposed configuration approach, a product configurator in a highly specific technical field of thermal insulation has been developed. Thermal insulating materials are mass products in themselves, but when installed on a specific building the final configured product is unique for each individual solution. This calls for greater customer involvement in the configuration process as the input data are unknown in the beginning due to the specific characteristics of each building. The results of testing the proposed configuration approach showed that the gained results were usable in practice regardless of the simplifications of the input data and calculations on the lower-level customer profiles.

This leads to the conclusion that if this approach is usable for customization of a product that requires high customer involvement and is unique for each solution, it could also be successfully used in the customization of products with more stable product structures, attributes and constraints. These products include capital goods such as buildings, machinery or tools. Further, they include consumer goods, both simple, such as shoes or clothing, and complex, such as cars, computers and furniture, or even services like insurance and tourism offers. If the possible structure of the product is known, regardless of its complexity, there is no need to have simplifications in the calculation algorithm, i.e. in the configuration algorithm. Following this logic, the input on lower customer profiles will give a more generalized description of customer requirements, while on higher level, customer requirements will be defined in greater detail. This will eventually lead to product solutions that will in each case be exact and correct but meet the exact requirements of customers to a greater or lesser extent in correspondence to the level of input and customer knowledge. Therefore the contribution of this research lies in the introduction of a product configuration approach that self-adapts the configuration process to the capabilities and needs of the customers, who can range from non-experts to experts in the related field of investigation.

Certain issues arise from the fact that the presented configurator is to be used by customers both with or without specific technical knowledge and from the fact that the configured product is connected to a specific technical field. One of the problematic points is that a simple configuration algorithm with a relatively small number of input data given by a non-expert customer may provide a somewhat incorrect result. However this same non-expert customer will benefit from having performed this configuration in any case. Should the customer then decide to purchase insulation material without expert help, they will still be better off and are more likely to make a "good purchase". In terms of directions for possible future research, this points towards the investigation of the limits of simplifying the configuration process. The other question at hand comes from the trend whereby nowadays customers buy complex products like computers and cars using product configurators even though they are far from being experts in the fields. When does a proposed configuration process become too complex and time demanding? How long before the customer becomes frustrated and decides to abort the process? Future research should thus focus on investigating what is the maximum possible engagement of the customer when using a product configurator and whether there are products that are not configurable at all by using product configurators. Understanding the limits of simplification and complexity will likely turn this specified configurator into a generally applicable, useful tool for mass customization.

**Acknowledgements**

This research is supported by *"Masterplast Yu"* Ltd.

# Appendix A: Example of Input Data

| Type of information | Type of building | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Building No. 1 | | | Building No. 2 | | | | |
| | Type of customer | | | Type of customer | | | | |
| | Beginner | Intermediate | | Beginner | Intermediate | | | |
| **General** | | | | | | | | |
| Area where the building is situated | | Normal | | | Normal | | | |
| Location of the building | | Protected | | | Protected | | | |
| Type of building | | Detached | | | Detached | | | |
| Cellar | No | No | | Yes | Yes | | | |
| Percentage of cellar underground [%] | 0 | 0 | | 40 | 40 | | | |
| Insulation of the cellar's walls | | No | | | No | | | |
| Insulation of the floor which is in contact with the ground | | No | | | No | | | |
| Number of floors in the building | 1 | 1 | | 2 | 2 | | | |
| Socle covered with plaster | | No | | | No | | | |
| Type of roof | 1 | 1 | | 6 | 6 | | | |
| Insulation type of loft | 2 | 2 | | 2 | 2 | | | |
| Loading of attic/loft, i.e. roof | | No | | | No | | | |
| Estimated area of the ground-plan of the building [m2] | 100 | | | 130 | | | | |
| High or low ceiling | Low | | | Low | | | | |
| Estimated total number of rooms | 6 | | | 12 | | | | |
| Estimated type of the building regarding the prevailing materials used | Full brick | | | Full brick | | | | |
| Previous insulation | No | | | No | | | | |
| Estimated quality of the windows and doors | Average | | | Average | | | | |
| **Specific** | | | | | | | | |
| **Level** | | First floor | Roof | | Cellar | First floor | Second floor | Roof |
| **Shape of the ground plan** | | 1 | 1 | | 4 | 4 | 4 | 4 |
| **Linear dimensions of the ground plan (circumferential dimensions) [m]** | | | | | | | | |
| d1 | | 11 | 11 | | 11 | 11 | 11 | 11 |
| d2 | | 9 | 9 | | 13 | 13 | 13 | 13 |
| d3 | | - | - | | 5 | 5 | 5 | 5 |
| d4 | | - | - | | 4 | 4 | 4 | 4 |
| d5 | | - | - | | 2 | 2 | 2 | 2 |
| **Height i.e. heights of the floor [m]** | | | | | | | | |
| h1 | | 3 | 3 | | 2.6 | 3 | 3 | 5 |
| h2 | | - | - | | - | - | - | 3 |
| h3 | | - | - | | - | - | - | 1 |
| **Percentage of free surface area of exterior walls of the building's floor [%]** | | | | | | | | |
| a1 | | 100 | 100 | | 100 | 100 | 100 | 100 |
| a2 | | 100 | 100 | | 100 | 100 | 100 | 100 |
| a3 | | 100 | 100 | | 100 | 100 | 100 | 100 |
| a4 | | 100 | 100 | | 100 | 100 | 100 | 100 |
| a5 | | - | - | | 100 | 100 | 100 | 100 |
| a6 | | - | - | | 100 | 100 | 100 | 100 |
| a7 | | - | - | | 100 | 100 | 100 | 100 |
| a8 | | - | - | | 100 | 100 | 100 | 100 |
| Correction of exterior surface of floor walls [m2] | | 0 | 0 | | 0 | 0 | 0 | 0 |
| Initial profile [m] | | 40 | 0 | | 48 | 0 | 0 | 0 |
| Edge protectors [m] | | 8 | 0 | | 12 | 0 | 0 | 0 |
| Number of wall layers | | 1 | 1 | | 2 | 2 | 2 | 2 |
| **Dominating type and thickness of the floor's wall** | | | | | | | | |
| Layer1 - type | | Full brick | Full brick | | Full brick | Full brick | Full brick | Full brick |
| Layer1 - thicness [m] | | 0.35 | 0.35 | | 0.35 | 0.35 | 0.35 | 0.35 |
| Layer2 - type | | - | - | | Plaster | Plaster | Plaster | Plaster |
| Layer2 - thicness [m] | | - | - | | 0.02 | 0.02 | 0.02 | 0.02 |
| Layer3 - type | | - | - | | - | - | - | - |
| Layer3 - thicness [m] | | - | - | | - | - | - | - |
| Layer4 - type | | - | - | | - | - | - | - |
| Layer4 - thicness [m] | | - | - | | - | - | - | - |
| Layer5 - type | | - | - | | - | - | - | - |
| Layer5 - thicness [m] | | - | - | | - | - | - | - |
| **Dominating type and thickness of the floor's (level's) floor** | | | | | | | | |
| Layer1 - type | | Armed concrete | Armed concrete | | Armed concrete | Armed concrete | Armed concrete | Armed concrete |
| Layer1 - thicness [m] | | 0.2 | 0.2 | | 0.2 | 0.2 | 0.2 | 0.2 |
| Layer2 - type | | - | - | | - | - | - | - |
| Layer2 - thicness [m] | | - | - | | - | - | - | - |
| Layer3 - type | | - | - | | - | - | - | - |
| Layer3 - thicness [m] | | - | - | | - | - | - | - |
| Layer4 - type | | - | - | | - | - | - | - |
| Layer4 - thicness [m] | | - | - | | - | - | - | - |
| Layer5 - type | | - | - | | - | - | - | - |
| Layer5 - thicness [m] | | - | - | | - | - | - | - |
| Correction of the surface area of the floor's (level's) floor [m2] | | 0 | 0 | | 0 | 0 | 0 | 0 |
| Dominating type, total surface area, and number of windows of the floor | | Wood double layer | - | | Wood double layer | PVC | PVC | PVC |
| Number of windows | | 4 | 0 | | 6 | 8 | 8 | 2 |
| Total surface area of all windows [m2] | | 6 | 0 | | 4 | 16 | 16 | 4 |
| Profiles for window joint [m] | | 0 | 0 | | 0 | 0 | 0 | 0 |
| PVC profile for balconies with glass net [m] | | 0 | 0 | | 0 | 0 | 0 | 0 |
| Dominating type, total surface area, and number of doors of the floor | | Wood | - | | PVC | Wood | - | - |
| Number of doors | | 2 | 0 | | 2 | 1 | 0 | 0 |
| Total surface area of all doors [m2] | | 4 | 0 | | 6 | 2 | 0 | 0 |

## Appendix B: Example of Calculated Bill of Materials

| Type of customer | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Beginer | | | | | | Intermediate | | | | | Professional | | | |
| Insulating materials | Material code | Amount | | Packaging | Relative deviation to detailed calculation | Material code | Amount | | Packaging | Relative deviation to detailed calculation | Material code | Amount | | Packaging |
| Styrodur | - | 0 | [m2] | 0 | 100.00% | 0510-25006000 | 125 | [m2] | 36 | 1.68% | 0510-25006000 | 127.13 | [m2] | 37 |
| Isomaster | 0501-08008000 | 230 | [m2] | 79 | 7.79% | 0501-08006000 | 248.77 | [m2] | 100 | 0.27% | 0501-08006000 | 249.44 | [m2] | 100 |
| Styrodur | 0510-30008000 | 13.5 | [m2] | 6 | 2.17% | 0510-30008000 | 13.15 | [m2] | 6 | 4.71% | 0510-30008000 | 13.8 | [m2] | 6 |
| Styrodur | 0510-30008000 | 46 | [m2] | 19 | 6.05% | 0510-30008000 | 46.08 | [m2] | 20 | 5.88% | 0510-30008000 | 48.96 | [m2] | 20 |
| Isomaster | - | 0 | [m2] | 0 | 100.00% | 0501-08006000 | 18.6 | [m2] | 5 | 2.77% | 0501-08006000 | 19.13 | [m2] | 5 |
| Isomaster | 0301-07010000 | 43.33 | [m2] | 18 | -0.74% | 0301-07010000 | 43.11 | [m2] | 18 | -0.23% | 0301-07010000 | 43.01 | [m2] | 18 |
| Isover rio twin | 0508-rt126000 | 101.07 | [m2] | 7 | -12.80% | 0508-rt126000 | 85.6 | [m2] | 6 | 4.46% | 0508-rt126000 | 89.6 | [m2] | 6 |
| Additional materials | Material code | Amount | | Packaging | Relative deviation to detailed calculation | Material code | Amount | | Packaging | Relative deviation to detailed calculation | Material code | Amount | | Packaging |
| Masterfix | 0103-10001005 | 49.92 | [l] | 11 | 33.63% | 0103-10001005 | 72.62 | [l] | 15 | 3.46% | 0103-10001005 | 75.22 | [l] | 16 |
| Masterfix | 0103-01101025 | 2026.5 | [kg] | 83 | 36.85% | 0103-01101025 | 3087 | [kg] | 124 | 3.81% | 0103-01101025 | 3209.15 | [kg] | 129 |
| Masternet | 0101-117wh055 | 318.45 | [m2] | 6 | 12.62% | 0101-117wh055 | 347.6 | [m2] | 7 | 4.63% | 0101-117wh055 | 364.46 | [m2] | 7 |
| Thermomaster | 0110-0z080000 | 46 | [m] | 23 | 50.00% | 0110-0z080000 | 92 | [m] | 46 | 0.00% | 0110-0z080000 | 92 | [m] | 46 |
| Ejot | 0111-03000000 | 23 | [pcs] | 1 | 50.00% | 0111-03000000 | 46 | [pcs] | 1 | 0.00% | 0111-03000000 | 46 | [pcs] | 1 |
| Ejot | 0112-03000000 | 46 | [pcs] | 1 | 50.00% | 0112-03000000 | 92 | [pcs] | 1 | 0.00% | 0112-03000000 | 92 | [pcs] | 1 |
| Ejot | 0112-05000000 | 46 | [pcs] | 1 | 50.00% | 0112-05000000 | 92 | [pcs] | 1 | 0.00% | 0112-05000000 | 92 | [pcs] | 1 |
| Ejot | 0112-10000000 | 46 | [pcs] | 1 | 50.00% | 0112-10000000 | 92 | [pcs] | 1 | 0.00% | 0112-10000000 | 92 | [pcs] | 1 |
| Thermomaster | 0118-00130250 | 920 | [pcs] | 4 | 7.79% | 0118-00130250 | 995.08 | [pcs] | 4 | 0.27% | 0118-00130250 | 997.76 | [pcs] | 4 |
| Plug dowel | 0717-64002000 | 230 | [pcs] | 2 | 50.00% | 0717-64002000 | 460 | [pcs] | 3 | 0.00% | 0717-64002000 | 460 | [pcs] | 3 |
| Thermomaster | 0105-10100000 | 8 | [m] | 4 | 66.67% | 0105-10100000 | 24 | [m] | 10 | 0.00% | 0105-10100000 | 24 | [m] | 10 |

## References


[1] C. Forza, F. Salvador: Product Information Management for Mass Customization, Palgrave Macmillan, London, UK, 2007

[2] S. Stankovski, M. Lazarević, G. Ostojić, I. Ćosić, R. Purić: RFID Technology in Product/Part Tracking during the Whole Life Cycle, Assembly Automation, Assembly Automation 29 (4) (2009) pp. 364-370

[3] X. Du, J. Jiao, M. M. Tseng: Understanding Customer Satisfaction in Product Customization, International Journal of Advanced Manufacturing Technology 31 (3/4) (2006) pp. 396-406

[4] Q. Zhang, M. M. Tseng: Modelling and Integration of Customer Flexibility in the Order Commitment Process for High Mix Low Volume Production, International Journal of Production Research 47 (22) (2009) pp. 6397-6416

[5] M. M. Tseng, R. J. Jiao, C. Wang: Design for Mass Personalization, CIRP Annals – Manufacturing Technology 59 (1) (2010) pp. 175-178

[6] D. Yang, R. Miao, W. Hongwei, Y. Zhou: Product Configuration Knowledge Modeling Using Ontology Web Language, Expert Systems with Applications 36 (3) (2009) pp. 4399-4411

[7] G. Zülch, H. I. Koruca, M. Börkircher: Simulation-supported Change Process for Product Customization – A Case Study in a Garment Company, Computers in Industry 62 (2011) pp. 568-577

[8] A. Trentin, E. Perin, C. Forza: Overcoming the Customization-Responsiveness Squeeze by Using Product Configurators: Beyond Anecdotal Evidence, Computers in Industry 62 (2011) pp. 260-268

[9] Z. Chen, I. Wang: Personalized Product Configuration Rules with Dual Formulations: a Method to Proactively Leverage Mass Confusion, Expert Systems with Applications 37 (1) (2010) pp. 383-392

[10] J. R. Galbraith: Designing the Customer-Centric Organization, Jossey-Bass, San Francisco, CA, 2005

[11] F. Salvador, C. Forza: Principles for Efficient and Effective Sales Configuration Design, International Journal of Mass Customisation 2 (1/2) (2007) pp. 114-127

[12] T. Blecker, N. Abdelkafi: Mass Customization: State of The Art and Challenges, in: T. Blecker, G. Friedrich (Eds.), Mass Customization: Challenges and Solutions, Springer, New York, NY, 2006, pp. 1-25

[13] P. Engelbrektsson, M. Soderman: The Use and Perception of Methods and Product Representations in Product Development: a Survey of Swedish Industry, Journal of Engineering Design 15 (2) (2004) pp. 141-154

[14] X. Luo, Y. Tu, J. Tang, C. K. Kwong: Optimizing Customer's Selection for Configurable Product in B2C e-commerce Application, Computers in Industry 59 (2008) pp. 767-776

[15] T. Leckner, M. Lacher: Simplifying Configuration through Customer-oriented Product Models, in: Proceedings of the International Conference on Engineering Design ICED 03, Stockholm, Sweden (2003)

[16] L. B. Romdhane, N. Fadhel, B. Ayeb: An Efficient Approach for Building Customer Profiles from Business Data, Expert Systems with Applications 37 (2010) pp. 1573-1585

[17] G. Hong, D. Xue, Y. Tu: Rapid Identification of the Optimal Product Configuration and its Parameters Based on Customer-Centric Product Modeling for One-of-a-Kind Production, Computers in Industry 61 (3) (2010) pp. 270-279

[18] M. Koch, K. Moeslein: User Representation in Ecommerce and Collaboration Applications, in: Proceedings of the 16th Bled eCommerce Conference eTransformation, Bled, Slovenia (2003) pp. 649-661

[19] Y. B. Cho, Y. H. Cho, S. H. Kim: Mining Changes in Customer Buying Behavior for Collaborative Recommendations, Expert Systems with Application 28 (2) (2005) pp. 359-369

[20] W. Fan, M. D. Gordon, P. Pathak: Effective Profiling of Consumer Information Retrieval Needs: A Unified Framework and Empirical Comparison, Decision Support Systems 40 (20) (2005) pp. 213-233

[21] S. S. Weng, M. J. Liu: Feature-based Recommendation for One-to-One Marketing, Expert Systems with Applications 26 (4) (2004) pp. 493-508

[22] X. Zhang, J. Edwards, J. Harding: Personalised Online Sales Using Web Usage Data Mining, Computers in Industry 58 (2007) pp. 772-782

[23] Y. Park, K. Chang: Individual and Group Behavior-based Customer Profile Model for Personalized Product Recommendation, Expert Systems with Application 36 (2009) pp. 1932-1939

[24] D. Lalic, K. Popovski, V. Gecevska, P.S. Vasilevska, T. Zdravko: Analysis of the Opportunities and Challenges for Renewable Energy Market in the Western Balkan Countries, Renewable and Sustainable Energy Reviews 15 (2011) pp. 3187-3195

[25] I. Sartori, A. G. Hestnes: Energy Use in the Life Cycle of Conventional and Low-Energy Buildings: A Review Article, Energy and Buildings 39 (2007) pp. 249-257

[26] N. Huberman, D. Pearlmutter: A Life-Cycle Energy Analysis of Building Materials in the Negev Desert, Energy and Buildings 40 (2008) pp. 837-848

[27] T. Ramesh, R. Prakash, K. K. Shukla: Life Cycle Energy Analysis of Buildings: An Overview, Energy and Buildings 42 (2010) pp. 1592-1600

[28] J. Morrissey, R. E. Horne: Life Cycle Cost Implications of Energy Efficiency Measures in New Residential Buildings, Energy and Buildings 43 (2011) pp. 915-924

[29] N. Daouas: A Study on Optimum Insulation Thickness in Walls and Energy Savings in Tunisian Buildings Based on Analytical Calculation of Cooling and Heating Transmission Loads, Applied Energy 88 (2011) pp. 156-164

[30] M. S. Alhomoud: Performance Characteristics and Practical Applications of Common Building Thermal Insulation Materials, Building and Environment 40 (2005) pp. 353-366

[31] E. R. Schramek: Taschenbuch für Heizung und Klimatechnik, R. Oldenbourg Verlag, München, Germany, 1995

[32] I. Fuerstner, Z. Anisic: Intelligent Product Configurator – the New Approach in Thermo Insulation of Buildings, Annals of the Faculty of Engineering Hunedoara 7 (2) (2009) pp. 165-170

[33] C. Chen: Human-centered Product Design and Development, Advanced Engineering Informatics 23 (2) (2009) pp. 140-141

[34] H. J. Zimmermann: Fuzzy Set Theory – and its Applications, Kluwer-Nijhoff Publishing, Boston, MA, 1997

[35] M. Takács: Multilevel Fuzzy Approach to the Risk and Disaster Management, Acta Polytechnica Hungarica 7 (4) (2010) pp. 91-102

[36] B. Zemeková, J. Talašová: Fuzzy Sets in HR Management, Acta Polytechnica Hungarica 8 (3) (2011) pp. 113-124