

# Adaptive Involvement of Customers as Co-Creators in Mass Customization

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## 1. Introduction

In the twenty-first century, a company has to organize around the customer in order to be a successful and viable firm. Today, the marketplace is customer driven. Customers expect to get what they would like, with a side order of customization. This approach raises several questions that have to be answered, one of which is that despite nowadays customers are knowledgeable in general, they are still far from being experts that can really co-create a product or a service (Galbraith, 2005). Companies are forced to change their activities from a seller's point of view towards a buyer's point of view, which results in a drastic increase of product variety offered by enterprises. That is one of the main characteristic trends of the modern economic system (Forza & Salvador, 2007). To maintain their competitiveness, companies are modularizing their products and introducing platform concepts, and this transfer from no customizable products to modular products that involve individual customer variants is one of the most important industrial strategies nowadays. The recent development of IT technology enables the software based product configuration systems that support the process of customized product development. They compose customer-specific solutions using the modules based on the customer's requirements.

These drastic changes in modern economy introduce mass customization that alters traditional product development and moves towards a two-stage model, the first, the realm of company/designer establishing the solution space and the second, that of the customer as co-designer. This second stage fundamentally changes the role of the customer from the consumer of a product, to a partner in a process of adding value (Reichwald et al., 2004).

This alteration of traditional product development through the involvement of the customer into the configuration of the final product faces some obvious problems. The fundamental challenge is to avoid the abortion of the configuration process by the customer. In many cases, the customer aborts the configuration process by himself. Major problem areas include the lack of a customer-desired option value regarding a specific attribute within the system as well as the inability of the customer to create definite preferences between certain option values. As a result, the customer aborts the configuration process and does not come up to the sales phase (Hansen et al., 2003). Also if customers are overwhelmed by the configuration task, there is a chance that they may abort the configuration process. Customers usually only want the product alternatives that exactly meet their requirements. If too much of a choice is offered, customers can feel frustrated or confused, and therefore incapable of making proper decisions. This overload of information is sometimes called

external complexity. This external complexity 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 (Blecker & Abdelkafi, 2006). Based on problem analysis regarding customers' involvement in the configuration process, the main areas of investigation to be considered are the minimization of the complexity experienced by the customers (Berger & Piller, 2003; Kumiawan et al., 2003) and the reduction of the cognitive overhead, considering not only the extent of choice, but also the lack of understanding about which solution meets their needs and also the uncertainties about the behavior of the supplier and the purchasing process (Franke & Piller, 2003). The chapter presents one approach in solving the presented problem, by the introduction of a methodology for adaptive involvement of customers as co-creators in mass customization of products and services.

## 2. Customer profile configuration

Generally, the identification and implementation of customer requirements are significant issues for successful product development (Engelbrektsson & Soderman, 2004). To be able to select or filter objects for an individual, information is needed about the individual (Levy & Weld, 2000; Schubert & Koch, 2002). Based on experience, the problem of adapting the process of co-creation to different customers can be solved by identification of different customer profiles that suit each individual customer's needs and limitations.

The area of customer profiles (Fig. 1) consists of general information about customers, which usually deals with basic and demographic attributes, information about specific product interests, information about general interests, information about relationships to other customers, information about the buying history and usage/interaction behavior and ratings of products, product components and certain attributes (Leckner & Lacher, 2003), specific information about customers, which is derived from input questions (Čović et al, 2009; Fürstner & Anišić, 2009a; Maravić et al., 2009) and contextual information about customers, such as time of the day, the date, etc. (Schubert & Koch, 2002; Koch & Moeslein, 2003).

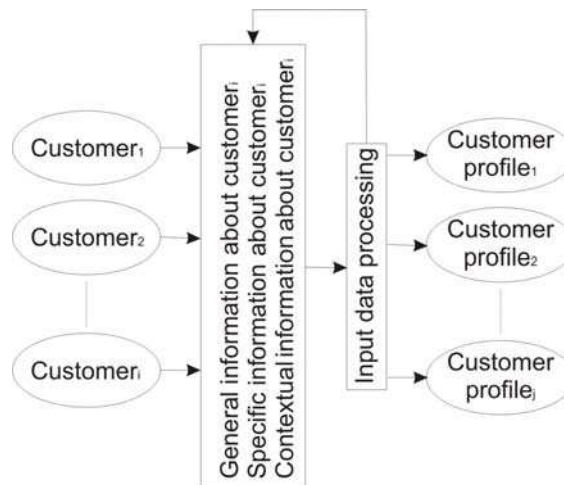


Fig. 1. Area of customer profiles

Voices of customers should not only be elicited at the front-end of the process, but rather frequently at various junctures along the process (Chong et al., 2009). Besides, not all the requirements can be known at the outset of the task (Gero & Kannengiesser, 2004). It is therefore necessary to collect customer opinions consistently.

The rest of the chapter deals with collecting and using specific information about customers, while general and contextual information about customers are not discussed here.

To configure the appropriate customer profile, specific information about customers is needed. Therefore a set of initial questions is asked at the beginning of the co-creation process.

There is a need to analyze the answers generated by each customer and to use them to form a customer profile. A number of approaches from the field of data analysis may be used, nevertheless the nature of the questions and the answers refer to the use of a non-crisp logic; therefore fuzzy logic is used to determine the appropriate customer profile (Zimmermann, 1988; Hanss, 2005; Bojadziev & Bojadziev, 2007).

The initial development of the theory of fuzzy sets was motivated by the perception that traditional techniques of systems analysis are not effective in dealing with problems in which the dependencies between variables are too complex or too ill-defined to admit of characterization by differential or difference equations. Such problems are the norm in biology, economics, psychology, linguistics, and many other fields. A common thread that runs through problems of this type is the unsharpness of class boundaries and the concomitant imprecision, uncertainty and partiality of truth. The concept of a fuzzy set is a reflection of this reality (Bojadziev & Bojadziev, 2007).

Generally, a fuzzy number  $A$  (Fig. 2) is defined on the universe  $R$  as a convex and normalized fuzzy set, by a membership function  $\mu_A(x)$  (Hanss, 2005; Bojadziev & Bojadziev, 2007).

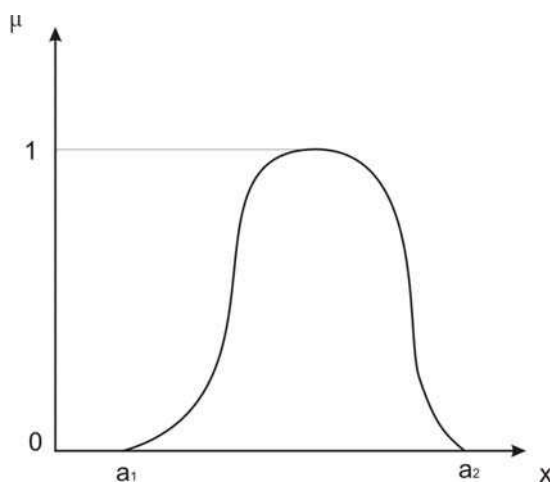


Fig. 2. Fuzzy number  $A$

The adaptive customer profile configurator is discussed by using trapezoidal (triangular) fuzzy numbers (Fig. 3). A trapezoidal fuzzy number  $A$  is defined on  $R$  by a following membership function (1).

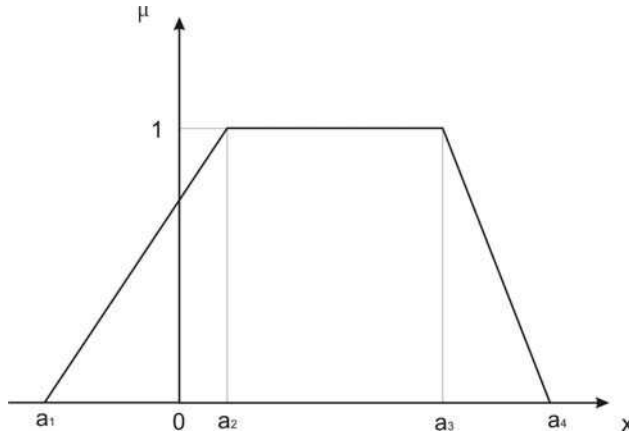


Fig. 3. Trapezoidal fuzzy number

$$\mu_A(x) = \begin{cases} 0, & x < a_1 \\ \frac{x - a_1}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ 1, & a_2 \leq x \leq a_3 \\ \frac{x - a_4}{a_3 - a_4}, & a_3 \leq x \leq a_4 \\ 0, & x > a_4 \end{cases} \quad (1)$$

Each question from the set of initial questions can have answers that can range from 0 to 1. 0 usually means that the answer is negative, 1 means that the answer is positive. Not only the answers are evaluated, but also the order of answering to questions. Also, during and after the process of co-creation, the customer’s feedback considering his satisfaction with a configured profile is analyzed and the profile is adapted according to the feedback. Based on asked questions and answers, several linguistic variables are defined, that can have different values. Next example shows a linguistic variable *a* that have three values (high, average and low) with the appropriate membership functions  $\mu(x)$  for the variable (Fig. 4).

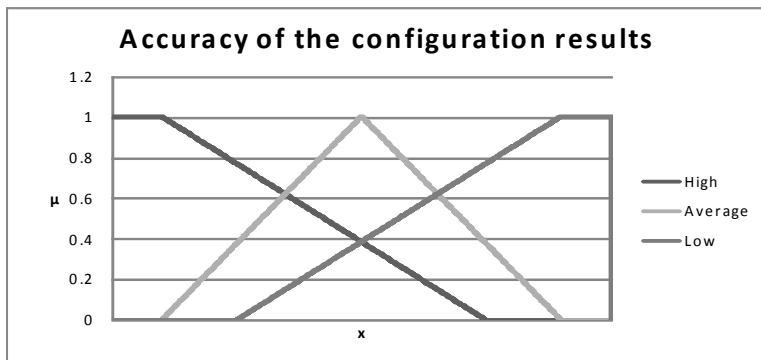


Fig. 4. Values for the linguistic variable

It was mentioned before that during the process of customer profile configuration, the order of answering the questions is also taken into consideration. The reason for doing so is that customers usually, based on their belief, sooner answer questions that are of higher importance to them than questions that are not. There is also a possibility that customers do not answer unimportant questions at all; then the value of the answer is 0.5 (Chen, 2009). For the same answer values (customer input), the membership functions change, based on the answering order. For the same variable, if the answer to the question is the first one, the membership functions taper, i.e. the equations are changed in the following manner (2).

$$\begin{aligned}\mu_{a=high}^{1st}(x) &= [\mu_{a=high}(x)]^{y_{high}} \\ \mu_{a=average}^{1st}(x) &= [\mu_{a=average}(x)]^{y_{average}}, \quad y_i \geq 1 \\ \mu_{a=poor}^{1st}(x) &= [\mu_{a=poor}(x)]^{y_{poor}}\end{aligned}\quad (2)$$

It results in a more unique response (Fig. 5).

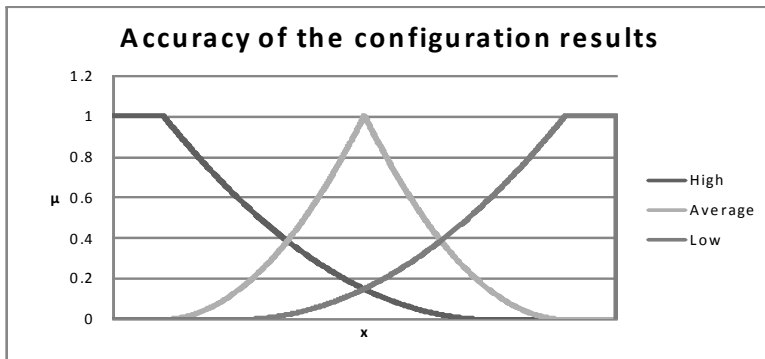


Fig. 5. Values for the linguistic variable

If the answer to the question is the last one, the membership functions expand, i.e. the equations are changed in the following manner (3).

$$\begin{aligned}\mu_{a=high}^{last}(x) &= [\mu_{a=high}(x)]^{y_{high}} \\ \mu_{a=average}^{last}(x) &= [\mu_{a=average}(x)]^{y_{average}}, \quad y_i \leq 1, \\ \mu_{a=poor}^{last}(x) &= [\mu_{a=poor}(x)]^{y_{poor}}\end{aligned}\quad (3)$$

It results in a more vague response (Fig. 6).

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,  $y_1 * y_2 * \dots * y_i$  if-then rules can be defined. The rules are designed to produce  $j$  different outputs  $o_j$  with defined membership functions (Fürstner & Anišić, 2009b; Fürstner & Anišić, 2009c). Next example (Fig. 7) shows an output with three possibilities defined by the following membership functions (4).

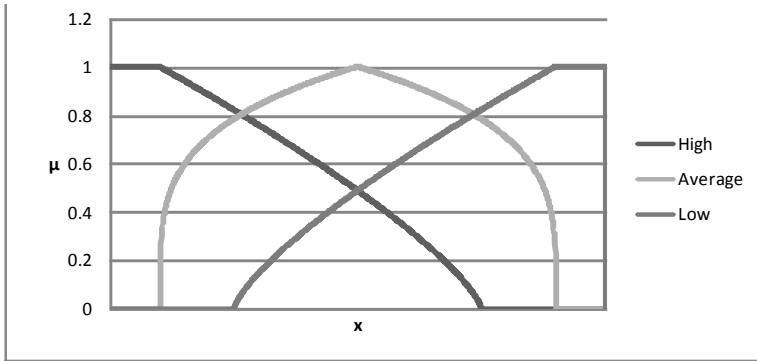


Fig. 6. Values for the linguistic variable

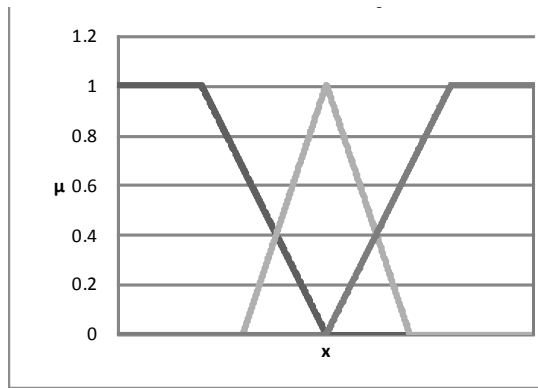


Fig. 7. Output

$$\begin{aligned}
 \mu_{o1}(x) &= \begin{cases} 1, & 0 \leq x \leq \alpha_0 \\ \frac{\beta_0 - x}{\beta_0 - \alpha_0}, & \alpha_0 < x \leq \beta_0 \\ 0, & \beta_0 < x \leq 1 \end{cases} \\
 \mu_{o2}(x) &= \begin{cases} 0, & 0 \leq x \leq \chi_0 \\ \frac{x - \chi_0}{\delta_0 - \chi_0}, & \chi_0 < x \leq \delta_0 \\ \frac{\varepsilon_0 - x}{\varepsilon_0 - \delta_0}, & \delta_0 < x \leq \varepsilon_0 \\ 0, & \varepsilon_0 < x \leq 1 \end{cases}, \\
 \mu_{o3}(x) &= \begin{cases} 0, & 0 \leq x \leq \phi_0 \\ \frac{x - \phi_0}{\phi_0 - \varphi_0}, & \phi_0 < x \leq \varphi_0 \\ 1, & \varphi_0 < x \leq 1 \end{cases}
 \end{aligned} \tag{4}$$

where  $\alpha_0, \beta_0, \chi_0, \delta_0, \varepsilon_0, \phi_0, \varphi_0$  are the initial values.

After the evaluation of if-then rules, an aggregated output is generated. Changes in input membership functions influence the customer profile configuration. For the same answers, but for a different answering order, the configured customer profile can be different (Fig. 8).

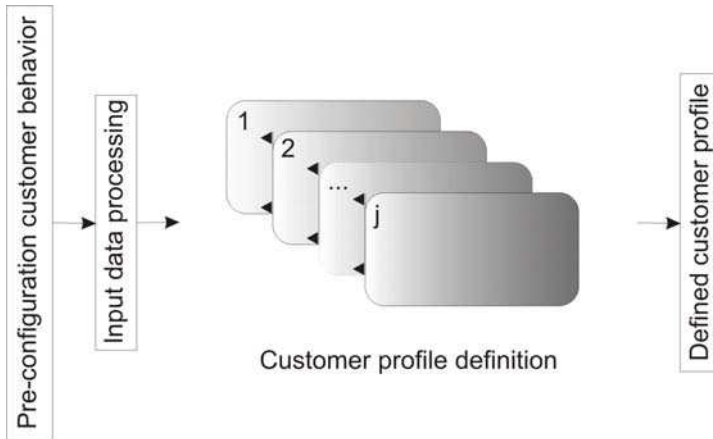


Fig. 8. Customer profile definition

After the configuration task is finished, a feedback is generated. The customer is asked to answer a new set of questions. Each question from the set can have answers that can range from -0.5 to 0.5. -0.5 usually means that the answer is negative, 0.5 means that the answer is positive. The answers to the questions are the feedback about how well the configurator has been adapted to 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 (for example for linguistic variable  $a$ ) are modified to new values (for example to linguistic variable  $a_{new}$ ) in the following manner (5).

$$a_{new} = a + \frac{feedback}{2}, \quad 0 \leq a_{new} \leq 1 \tag{5}$$

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 in the future, are shifted left or right to better articulate the future customers’ preferences (Fig. 9).

The amount of shifting ( $sa$ ) is calculated in the following manner (6).

$$sa = \frac{o - o_{new}}{10} \tag{6}$$

The division by 10 is used to assure that the shift is not too big. The resulted customer profile generation algorithm is shown in Fig. 10.

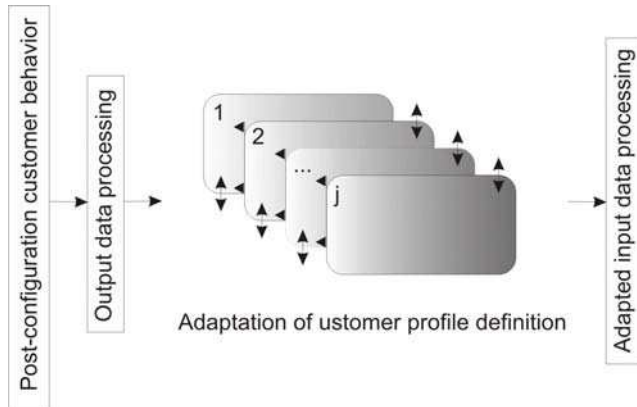


Fig. 9. Adapted input data processing

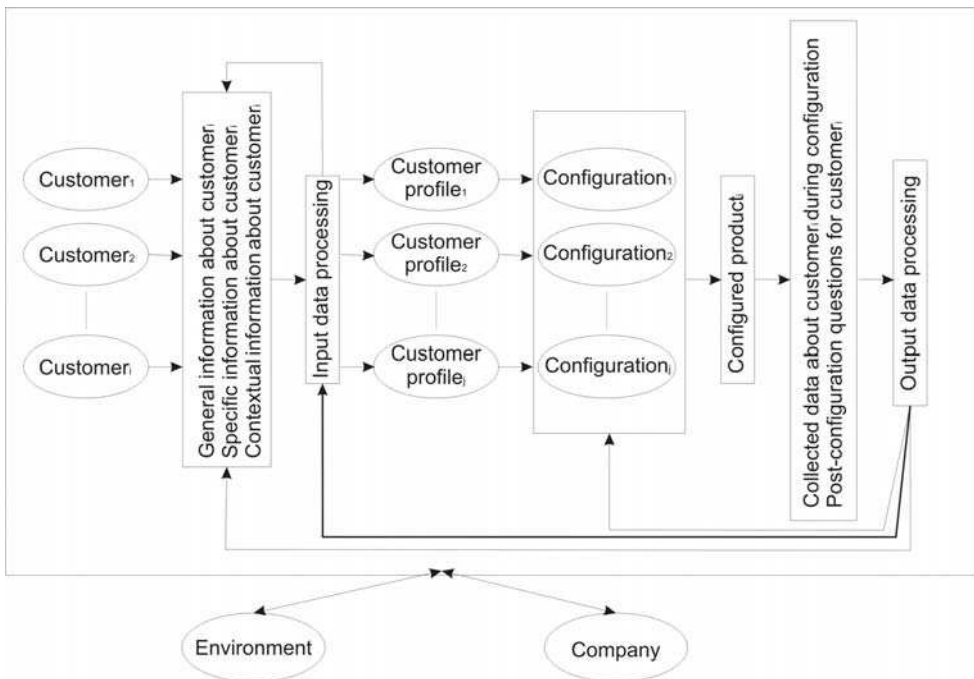


Fig. 10. Customer profile generation



### 3. Case study

The customer profile generation and the usage of different customer profiles in the process of co-creation are tested on a developed configurator for thermal insulation of buildings with the following characteristics (Fürstner & Anišić, 2009a; Fürstner & Anišić, 2009b, Fürstner & Anišić, 2009c):

- The configurator has to offer web based on-line instant results;
- The result should be based on the latest results in research and practice;
- The configurator should configure customized results, based on the specific characteristics of individual buildings;
- The configurator has to minimize the potential complexity experienced by the customer, by reduction of cognitive overhead;
- The configurator has to be used by professionals, retailers and end customers without specific technical knowledge about thermal insulation;
- The configurator should offer an accurate enough result, which is acceptable in the research field;
- The configurator has to raise the awareness about the necessity and the advantages of proper thermal insulation.

The algorithm for determination of thermal insulation of buildings is not discussed in this paper.

Previously developed configurator that was meant to be used both by customers with average or no technical knowledge and by professionals with proper technical knowledge in the related field of investigation had some limitations, because some of the previous non-professional customers had found the product configurator too complex to use. On the other hand some of the professional customers have found that the configurator lacked the possibility of defining exact and precise input parameters. Other problems included the need for more or less accurate results, as well as more or less time-consuming configuration. These problems were solved by identification of three different customer profiles:

- "Dummy" customer;
- Intermediate customer;
- Professional customer.

The "Dummy" 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 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 proper knowledge about the problem of thermal insulation; it may also be a customer with average technical knowledge about thermal insulation but with more time for completing the configuration process or with a need for more accurate result, etc.

To configure the appropriate customer profile, three initial questions are asked before the start of the configuration process:

- What is your estimate about 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 triangular or trapezoidal, and are chosen based on previous testing and experience (7), (8), (9), where the variables are described on the operating domain of  $x = [0,1]$  (Fürstner & Anišić, 2009b; Fürstner & Anišić, 2009c).

$$\begin{aligned}
 \mu_{k=very\_poor}(x) &= \left\{ \begin{array}{ll} 1, & 0 \leq x \leq 0.05 \\ \frac{0.5-x}{0.5-0.05}, & 0.05 < x \leq 0.5 \\ 0, & 0.5 < x \leq 1 \end{array} \right\} \\
 \mu_{k=poor}(x) &= \left\{ \begin{array}{ll} \frac{x}{0.3}, & 0 \leq x \leq 0.3 \\ \frac{0.6-x}{0.6-0.3}, & 0.3 < x \leq 0.6 \\ 0, & 0.6 < x \leq 1 \end{array} \right\} \\
 \mu_{k=average}(x) &= \left\{ \begin{array}{ll} 0, & 0 \leq x \leq 0.2 \\ \frac{x-0.2}{0.5-0.2}, & 0.2 < x \leq 0.5 \\ \frac{0.8-x}{0.8-0.5}, & 0.5 < x \leq 0.8 \\ 0, & 0.8 < x \leq 1 \end{array} \right\} \quad (7) \\
 \mu_{k=good}(x) &= \left\{ \begin{array}{ll} 0, & 0 \leq x \leq 0.4 \\ \frac{x-0.4}{0.7-0.4}, & 0.4 < x \leq 0.7 \\ \frac{1-x}{1-0.7}, & 0.7 < x \leq 1 \end{array} \right\} \\
 \mu_{k=very\_good}(x) &= \left\{ \begin{array}{ll} 0, & 0 \leq x \leq 0.5 \\ \frac{x-0.5}{0.95-0.5}, & 0.5 < x \leq 0.95 \\ 1, & 0.95 < x \leq 1 \end{array} \right\}
 \end{aligned}$$

$$\mu_{a=high}(x) = \begin{cases} 1, & 0 \leq x \leq 0.1 \\ \frac{0.75-x}{0.75-0.1}, & 0.1 < x \leq 0.75 \\ 0, & 0.75 < x \leq 1 \end{cases}$$

$$\mu_{a=average}(x) = \begin{cases} 0, & 0 \leq x \leq 0.1 \\ \frac{x-0.1}{0.5-0.1}, & 0.1 < x \leq 0.5 \\ \frac{0.9-x}{0.9-0.5}, & 0.5 < x \leq 0.9 \\ 0, & 0.9 < x \leq 1 \end{cases} \quad (8)$$

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

$$\mu_{t=enough}(x) = \begin{cases} 1, & 0 \leq x \leq 0.1 \\ \frac{0.75-x}{0.75-0.1}, & 0.1 < x \leq 0.75 \\ 0, & 0.75 < x \leq 1 \end{cases}$$

$$\mu_{t=average}(x) = \begin{cases} \frac{x-0.1}{0.5-0.1}, & 0 \leq x \leq 0.5 \\ \frac{0.9-x}{0.9-0.5}, & 0.5 < x \leq 1 \end{cases} \quad (9)$$

$$\mu_{t=not\_enough}(x) = \begin{cases} 0, & 0 \leq x \leq 0.25 \\ \frac{x-0.25}{0.25-0.9}, & 0.25 < x \leq 0.9 \\ 1, & 0.9 < x \leq 1 \end{cases}$$

For the same answer values (customer input), the membership functions change, based on the answering order. If the answer to the question is the first one, the membership functions taper (10), what results in a more unique response.

$$\mu_{k=very\_poor}^{1st}(x) = [\mu_{k=very\_poor}(x)]^2$$

$$\mu_{k=poor}^{1st}(x) = [\mu_{k=poor}(x)]^2$$

$$\mu_{k=average}^{1st}(x) = [\mu_{k=average}(x)]^2 \quad (10)$$

$$\mu_{k=good}^{1st}(x) = [\mu_{k=good}(x)]^2$$

$$\mu_{k=very\_good}^{1st}(x) = [\mu_{k=very\_good}(x)]^2$$

$$\begin{aligned}\mu_{a=high}^{1st}(x) &= [\mu_{a=high}(x)]^2 \\ \mu_{a=average}^{1st}(x) &= [\mu_{a=average}(x)]^2 \\ \mu_{a=poor}^{1st}(x) &= [\mu_{a=poor}(x)]^2 \\ \\ \mu_{t=enough}^{1st}(x) &= [\mu_{t=enough}(x)]^2 \\ \mu_{t=average}^{1st}(x) &= [\mu_{t=average}(x)]^2 \\ \mu_{t=not\_enough}^{1st}(x) &= [\mu_{t=not\_enough}(x)]^2\end{aligned}$$

If the answer to the question is the last one, the membership functions expand, what results in a more vague response.

$$\begin{aligned}\mu_{k=very\_poor}^{1st}(x) &= [\mu_{k=very\_poor}(x)]^{0.9} \\ \mu_{k=poor}^{1st}(x) &= [\mu_{k=poor}(x)]^{0.75} \\ \mu_{k=average}^{1st}(x) &= [\mu_{k=average}(x)]^{0.25} \\ \mu_{k=good}^{1st}(x) &= [\mu_{k=good}(x)]^{0.75} \\ \mu_{k=very\_good}^{1st}(x) &= [\mu_{k=very\_good}(x)]^{0.9} \\ \\ \mu_{a=high}^{last}(x) &= [\mu_{a=high}(x)]^{0.25} \\ \mu_{a=average}^{last}(x) &= [\mu_{a=average}(x)]^{0.75} \\ \mu_{a=poor}^{last}(x) &= [\mu_{a=poor}(x)]^{0.25} \\ \\ \mu_{t=enough}^{last}(x) &= [\mu_{t=enough}(x)]^{0.25} \\ \mu_{t=average}^{last}(x) &= [\mu_{t=average}(x)]^{0.75} \\ \mu_{t=not\_enough}^{last}(x) &= [\mu_{t=not\_enough}(x)]^{0.25}\end{aligned} \tag{11}$$

As an example, for the same customer input (answer to the first question) of 0.65, but for different answering order, the membership functions are different, i.e. the values of the membership functions are also different, which is shown in Fig. 11.

The fuzzy output from the system, i.e. the decision is made in a manner that 45 if-then rules are defined. The rules are designed to produce three different outputs (o): "dummy", intermediate and professional. The membership functions in Fig. 12 are triangular or trapezoidal (12)

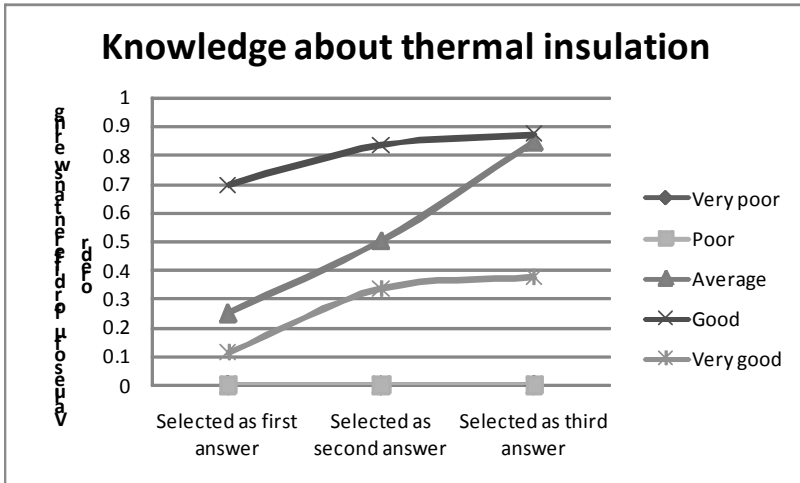


Fig. 11. Different values of the membership functions for different answering order

$$\mu_{o=dummy}(x) = \begin{cases} 1, & 0 \leq x \leq \alpha_0 \\ \frac{\beta_0 - x}{\beta_0 - \alpha_0}, & \alpha_0 < x \leq \beta_0 \\ 0, & \beta_0 < x \leq 1 \end{cases}, \text{ where } \begin{matrix} \alpha_0 = 0.2 \\ \beta_0 = 0.5 \end{matrix} \text{ are the initial values}$$

$$\mu_{o=intermediate}(x) = \begin{cases} 0, & 0 \leq x \leq \chi_0 \\ \frac{x - \chi_0}{\delta_0 - \chi_0}, & \chi_0 < x \leq \delta_0 \\ \frac{\varepsilon_0 - x}{\varepsilon_0 - \delta_0}, & \delta_0 < x \leq \varepsilon_0 \\ 0, & \varepsilon_0 < x \leq 1 \end{cases}, \text{ where } \begin{matrix} \chi_0 = 0.3 \\ \delta_0 = 0.5 \\ \varepsilon_0 = 0.7 \end{matrix} \text{ are the initial values} \quad (12)$$

$$\mu_{o=professional}(x) = \begin{cases} 0, & 0 \leq x \leq \phi_0 \\ \frac{x - \phi_0}{\varphi_0 - \phi_0}, & \phi_0 < x \leq \varphi_0 \\ 1, & \varphi_0 < x \leq 1 \end{cases}, \text{ where } \begin{matrix} \phi_0 = 0.5 \\ \varphi_0 = 0.8 \end{matrix} \text{ are the initial values.}$$

After the evaluation of if-then rules, an aggregated output is generated. Changes in input membership functions influence the customer profile configuration. For the same answers, but for a different answering order, the configured customer profile can be different.

The next example shows that for the following input data:

- 1st answer - customer input for knowledge about thermal insulation is 0.65;
- 2nd answer - customer input for accuracy of the configuration results is 0.8;
- 3rd answer - customer input for time for the configuration process is 0.5, after defuzzification by the "Center of gravity method", the crisp output is 0.387 - and is interpreted as an "Intermediate customer".

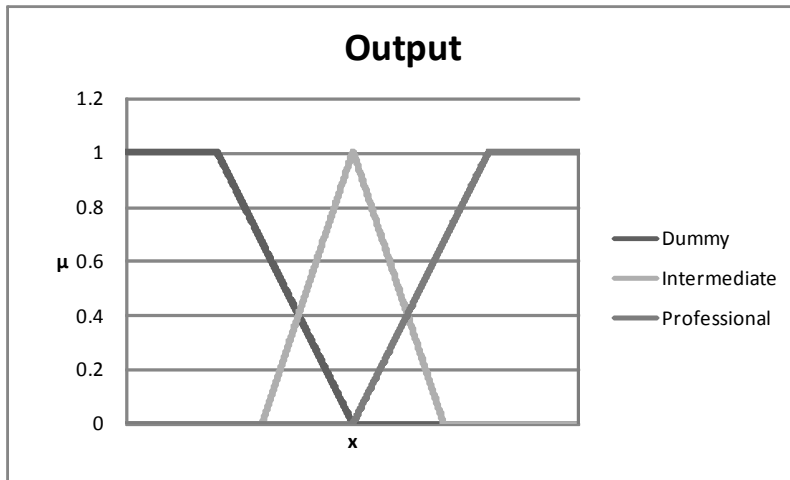


Fig. 12. Membership functions for output

For the following input data:

- 1st answer - customer input for accuracy of the configuration results is 0.8;
  - 2nd answer - customer input for knowledge about thermal insulation is 0.65;
  - 3rd answer - customer input for time for the configuration process is 0.5,
- after defuzzification by the same method, the crisp output is 0.369 - and is interpreted as a "Dummy customer".

Based on the previous example, one can conclude that for the same input data, but for a different answering order, different customer profiles can be configured.

After the configuration task is finished, a feedback is generated. The customer is asked to answer a set of three 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  $k_{new}$ ,  $a_{new}$ ,  $t_{new}$  (13).

$$\begin{aligned}
 k_{new} &= k + \frac{c}{2} & 0 \leq k_{new} \leq 1 \\
 a_{new} &= a + \frac{s}{2}, & 0 \leq a_{new} \leq 1 \\
 t_{new} &= t + \frac{i}{2} & 0 \leq t_{new} \leq 1
 \end{aligned} \tag{13}$$

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 in the future, are shifted left or right to better articulate the customers' preferences in the future. The amount of shifting is calculated in the following manner (6) as it was discussed before. The shifted membership functions for  $o$  are (14), with the following corrections (15).

$$\mu_{o=dummy}^{i+1}(x) = \left\{ \begin{array}{ll} 1, & 0 \leq x \leq \alpha_{i+1} = (\alpha_i + sa) \\ \frac{\beta_{i+1} - x}{\beta_{i+1} - \alpha_{i+1}}, & \alpha_{i+1} = (\alpha_i + sa) < x \leq \beta_{i+1} = (\beta_i + sa) \\ 0, & \beta_{i+1} = (\beta_i + sa) < x \leq 1 \end{array} \right\}$$

$$\mu_{o=intermediate}^{i+1}(x) = \left\{ \begin{array}{ll} 0, & 0 \leq x \leq \chi_{i+1} = (\chi_i + sa) \\ \frac{x - \chi_{i+1}}{\delta_{i+1} - \chi_{i+1}}, & \chi_{i+1} = (\chi_i + sa) < x \leq \delta_{i+1} = (\delta_i + sa) \\ \frac{\varepsilon_{i+1} - x}{\varepsilon_{i+1} - \delta_{i+1}}, & \delta_{i+1} = (\delta_i + sa) < x \leq \varepsilon_{i+1} = (\varepsilon_i + sa) \\ 0 & \varepsilon_{i+1} = (\varepsilon_i + sa) < x \leq 1 \end{array} \right\} \quad (14)$$

$$\mu_{o=professional}^{i+1}(x) = \left\{ \begin{array}{ll} 0, & 0 \leq x \leq \phi_{i+1} = (\phi_i + sa) \\ \frac{x - \phi_{i+1}}{\phi_{i+1} - \varphi_{i+1}}, & \phi_{i+1} = (\phi_i + sa) < x \leq \varphi_{i+1} = (\varphi_i + sa) \\ 1, & \varphi_{i+1} = (\varphi_i + sa) < x \leq 1 \end{array} \right\}$$

$$\begin{aligned} & \text{if } \alpha_{i+1} < 0.05 \text{ then } \alpha_{i+1} = 0.05; \text{ if } \alpha_{i+1} > 0.35 \text{ then } \alpha_{i+1} = 0.35 \\ & \text{if } \beta_{i+1} < 0.35 \text{ then } \beta_{i+1} = 0.35; \text{ if } \beta_{i+1} > 0.65 \text{ then } \beta_{i+1} = 0.65 \\ & \text{if } \chi_{i+1} < 0.15 \text{ then } \chi_{i+1} = 0.15; \text{ if } \chi_{i+1} > 0.45 \text{ then } \chi_{i+1} = 0.45 \\ & \text{if } \delta_{i+1} < 0.35 \text{ then } \delta_{i+1} = 0.35; \text{ if } \delta_{i+1} > 0.65 \text{ then } \delta_{i+1} = 0.65 \\ & \text{if } \varepsilon_{i+1} < 0.55 \text{ then } \varepsilon_{i+1} = 0.55; \text{ if } \varepsilon_{i+1} > 0.85 \text{ then } \varepsilon_{i+1} = 0.85 \\ & \text{if } \phi_{i+1} < 0.35 \text{ then } \phi_{i+1} = 0.35; \text{ if } \phi_{i+1} > 0.65 \text{ then } \phi_{i+1} = 0.65 \\ & \text{if } \varphi_{i+1} < 0.65 \text{ then } \varphi_{i+1} = 0.65; \text{ if } \varphi_{i+1} > 0.95 \text{ then } \varphi_{i+1} = 0.95 \end{aligned} \quad (15)$$

### 3.1 First results

The developed configurator has been tested configuring five existing buildings. The insulation is configured and the results are calculated for each customer profile. Heat loss is calculated, for input temperatures that are shown in Fig. 13.

Heat losses without insulation and with the proposed insulation, for different customer profiles are shown in Fig. 14 and Fig. 15, respectively.

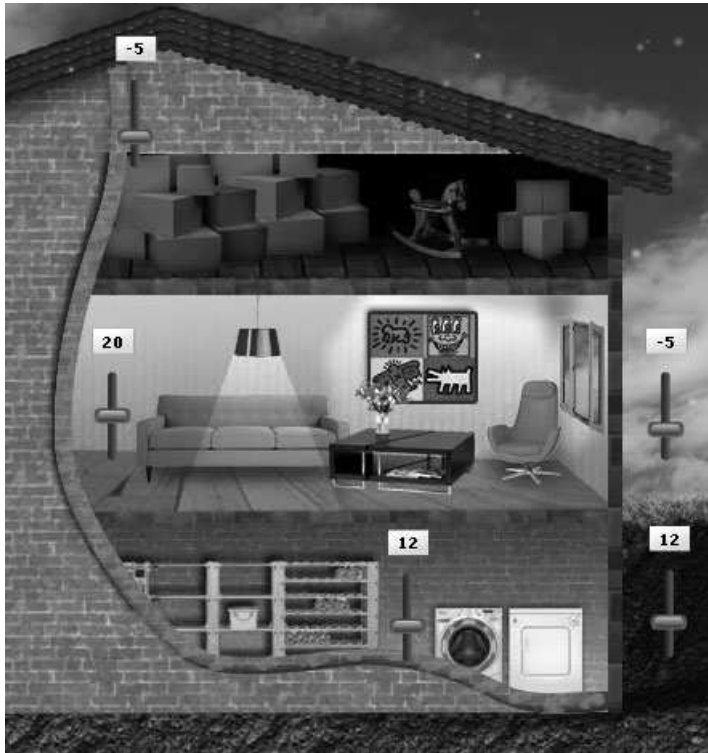


Fig. 13. Input temperatures

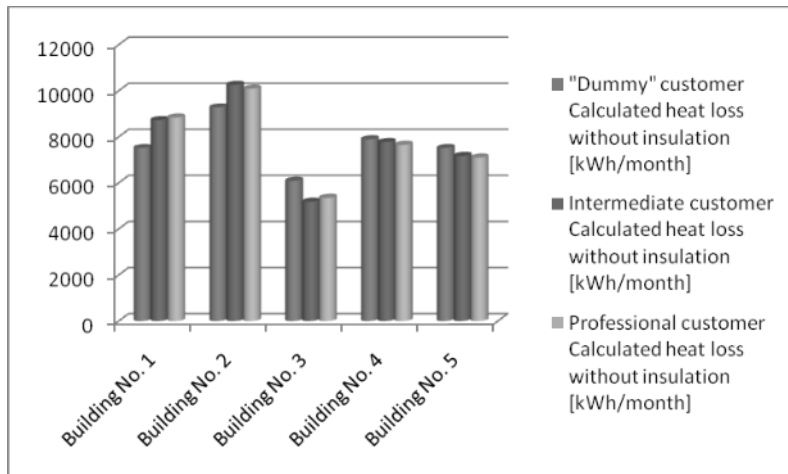


Fig. 14. Calculated heat loss without insulation



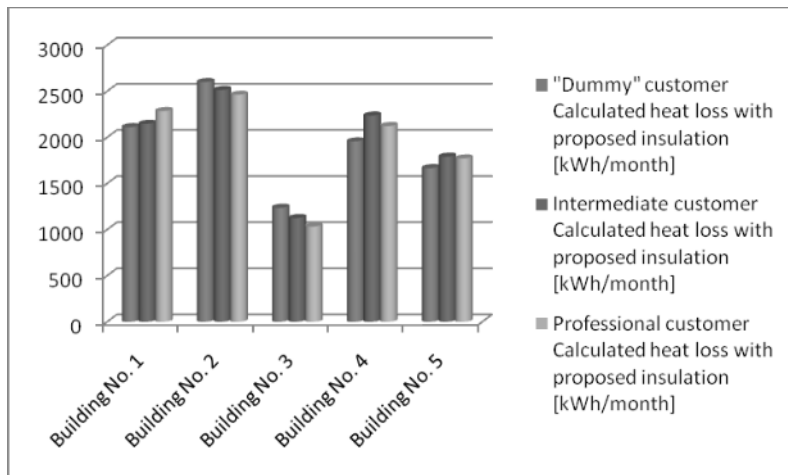


Fig. 15. Calculated heat loss with proposed insulation

Relative deviations of calculated heat losses without insulation and with the proposed insulation, for different customer profiles compared to detailed calculations are shown in Fig. 16 and Fig. 17, respectively.

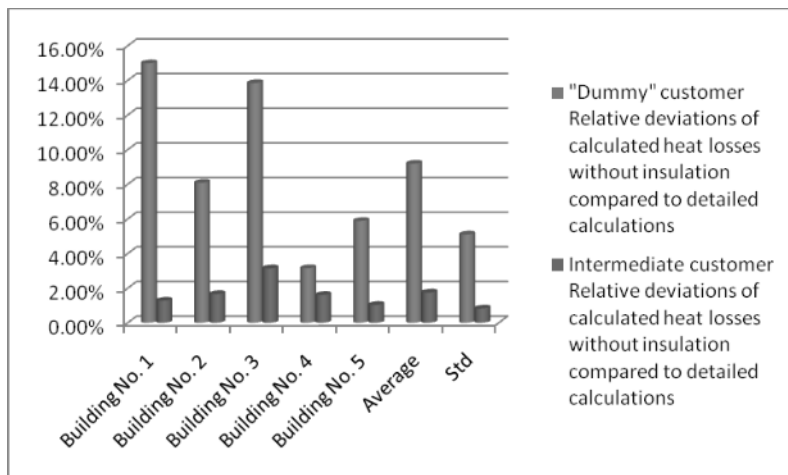


Fig. 16. Relative Deviations from detailed calculation without insulation

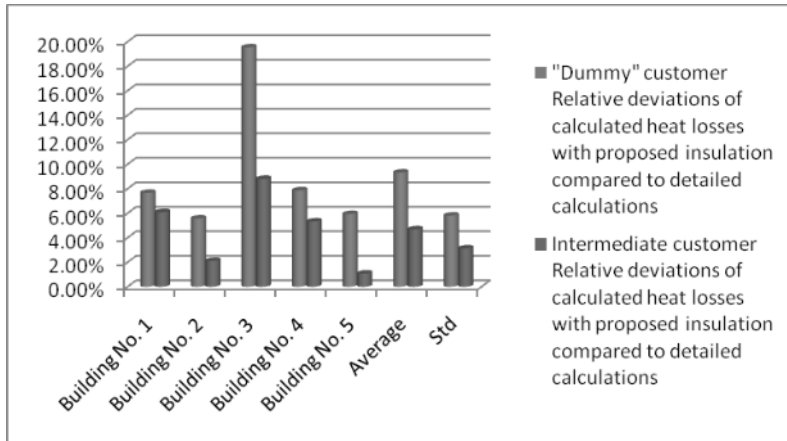


Fig. 17. Relative Deviations from detailed calculation with proposed insulation

#### 4. Conclusion

The fact that in modern economy traditional product development is changed and moved towards a two-stage model, the first, the realm of company/designer establishing the solution space and the second, that of the customer as co-designer, fundamentally changes the role of the customer from the consumer of a product, to a partner in a process of adding value. This alteration of traditional product development through the involvement of the customer into the configuration of the final product faces some obvious problems. The fundamental challenge is to avoid the abortion of the configuration process by the customer. The presented problem is solved by a proposed methodology for adaptive involvement of customers as co-creators in mass customization of products and services. The developed methodology identifies different customer profiles that suit each individual customer's needs and limitations.

The developed methodology is tested on a product configurator for thermal insulation of buildings. First results show that average deviation from the exact calculations for the "dummy" customer range from approximately 9.19% for calculations without thermal insulation to 9.31% for calculations with thermal insulation. Average deviation for the intermediate customer ranges from approximately 1.74% for calculations without thermal insulation to 4.68% for calculations with thermal insulation. Based on these results one can conclude that different customer profiles give different results, but that the differences could be accepted if the nature of the research field is taken into consideration.

The configuration process in the case of the "dummy" customer lasts about 3-4 minutes, for the intermediate customer the required time is about 5-10 minutes, and for the professional customer it takes more. The final solution is given in understandable form, which can be directly used for ordering. These results show that different customer profiles could be necessary for successful completion of the configuration process.

Experiences from retailers suggest that the idea of insulating a building is becoming more appealing and acceptable for the customers, when presented using the configurator, while end users suggest that there is further need to make the configurator more interesting.

The results and the gained experiences point towards several future research directions:

- Making the user interface more interesting by using as many visual and interactive elements as possible with real time multimedia help;
- Definition of rules for taking into account the accepted solutions by previous customers of certain profile and their incorporation into configurator;
- Development of an intelligent decision making algorithm that takes into consideration the general, specific and contextual information about customers during the customer profile generation as well as during the configuration process.

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