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DESIGN TOOL FOR SOLAR PANELS PRODUCT CUSTOMIZATION

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Abstract: *For producer, Mass Customization (MC) represents an effort to balance between level of design and production customization for individual customers on one side, and reduction of production costs on other side. By MC production could became more efficient and costs can be reduced. Paper deals with of internet interaction design tool development for solar water heating panells product in order to provide customer choice of limited offered options in configuration of their own individual product. In that way, it is possible to organize more efficient production process with reduced production lead time, and achieve better estimation of product cost and delivery time.*

Key Words: ***Solar panels, Configurator, Internet interaction tool, Lean manufacturing***

1. INTRODUCTION

Number of customers and their demands frequently changes, forcing producers to cope with larger variability in production. Despite higher production costs, interest in the MC products is often higher than for comparable cheaper standardized products.

The emphasis has shifted from price to value, and research shows that the buyer, who has previously purchased a standard product, is willing to pay a premium (often 10-50%) because they believe that the products which are customized gives higher value than standardized and better suit their needs. Despite higher production costs, therefore, interest in the MC products is often higher than for comparable standardized products because there are frequent cases where products which are specified suited to the customer much better than the best available standard product.

A research [1] done in over 200 different companies from over 8 different countries has shown that if MC is correctly understood and implemented it represents a strategic mechanism that can be applied in most types of businesses. MC will not take the company and its trade into an idealized state where it will know what a customer wants and what goods to produce in order to satisfy the individualized customer requirements at the mass production price.

2. DEVELOPMENT OF MASS PRODUCTION TOWARDS MASS CUSTOMIZATION

Customers were demanding a variety of products and mass production could not meet such needs, which led to early research on strategies and new ways to achieve competitive advantage. Experts have concluded that the competitiveness can no longer be based on price, but on fast delivery, quality and product flexibility. While the mass production for an unknown buyer is determined by the product manufacturing resources, which led to the marketing plan and to the final customer, the modern production process is exactly the opposite. In modern manufacturing with collaboration of the customer and the appropriate team, and by using common resources, a solution that meets customer needs is achieved. The life cycle of the product is still reducing while the diversity of product range is increasing, thereby giving a new dimension to the concept of mass customization of products.

The MC concept is derived from a combination of two contradictory concepts: "mass production" and "customization". One way to reduce cost is to produce individual product components separately, which only has to be assembled at the end of the manufacturing process. Manufacturers fragment the production process, resulting in a saving of time and reorganizing the production of products in a way that some parts and semi products become available before customer orders them as a part of final product. The division of production is the key for the shortening of delivery time, which also provides the MC with a relatively low cost to the company. In an ideal version of MC, production should not begin before the customer buys the product. But in reality, for many industries, it is impossible to apply it in full content. Producers should have some stock available and some parts of production in progress to achieve delivery within the available time. Competitive advantages of MC are based on combining the efficiency of mass production with a variety of customization options. Among the many challenges of MC few of the most important are to:

a. maintain a low cost that could compete with standardized products,
b. achieve high quality production, despite the great diversity of products,
c. ensure product availability at a time when the customer wants it.

3. DEVELOPMENT OF THE CONFIGURABLE PRODUCTS

So far it has not been proven that any kind of production can make the entire production process more efficient than

the mass production. Therefore, it can be concluded that with the increasing demands of a product, manufacturing process of the company, which produces such a product should have the characteristics of mass production. Businesses want, with increasing market demands, to achieve a number of re-use, but not in terms of re-use of the product after it has achieved its primary application, but re-use of components, documentation, production processes etc. Businesses are faced with the challenge of ensuring greater variability of the product on the market, but with a small difference (in construction, manufacturing, maintenance,) among the variants. Therefore, the development of product variants should be considered as a configuration of new products from previously defined modules, or based on same product platforms.

Creating a basic unit into which different components (modules) can be fitted thus enabling different variants of the same product to be produced is considered to be one of the most important aspects of modular production.

Basis has to be capable of supporting, with its structure and use, all expected product variants. Individual components must therefore bear characteristics which placed together create complex products [2].

The key to successful product family lies in creation of a platform as a base for existing module installation. Companies use product platform in order to increase number or variants and shorten product delivery time, lower expenses and satisfy customer needs. There are a major number of papers that deal with possibilities, tools and methods of implementation families and product platform of various forms.

Certain authors advocate modular product implementation and analyze product development process, modular project, Design for modularity (DFM), design for manufacture and assembly, flexibility and cellular manufacturing system [3].

With the reduction in construction time, the cost of construction is reduced, while reducing production costs results from the use of ready to install modules, that is derived from mass production of these modules. This case shows the importance of developing a system for configuring variants of modular product architecture based on customer requirements. The realization of such systems requires the definition of information models to support product configuration based on customer requirements, and implementation of computer systems in a networked environment [4].

4. SOLAR PANEL PRODUCTION

4.1. Solar energy

The fact is that conventional energy sources (coal, oil, gas, nuclear fuel) are limited and inexhaustible, and that the energy sector is largely the cause of SO_2, NO_x, and particularly the greenhouse gas carbon dioxide CO_2, which largely contributes to global warming and climate change. Because of this, energy must be derived from new energy sources, such as the solar energy, wind energy, small streams, geothermal energy, biomass and waste, tidal energy, the energy of ocean currents and waves, hydrogen, etc. and usage of them is important from many aspects for energy and economic system of each country.

Solar energy is a renewable and unlimited source of energy which, directly or indirectly, derives most of the other sources of energy on Earth. Solar energy in the narrow sense means the amount of energy that is transmitted by solar radiation. Its unit is J, but it is more commonly used kWh. The transfer of solar energy is achieved by radiation. Solar shortwave radiation is the radiation that reaches the Earth from the Sun. His unit is W/m^2.

4.2. Curent state of solar energy usage in Croatia

The technology of solar system is easy to use, easy to install, resistant to climatic influences, easily upgraded if necessary, and service and maintenance costs are minimal. Unfortunately, currently the Republic of Croatia, although it has very favorable conditions for the use of solar energy and it is incomparably better than many countries, is at the very bottom of Europe in the number of installed solar systems. The positive is that the few counties in Croatia, in cooperation with the Fund for Environmental Protection and Energy, announced a public tender for co-installation of solar systems in households with individual customers. Karlovac County financed the installation of solar collectors for the 60 households, with 40% of total investments, up to the maximum amount of 12.000 Euros per household. Krapina-Zagorje County also financed the installation of 20 households with 40% of total investments. Zagreb County financed the installation of solar systems for 50 households in the amount of 40% of total investments. 130 of these households will reduce carbon dioxide emissions into the environment for more than 110 tons per year (when compared to thermal energy instead of solar collectors produced by combustion of fossil fuels) [5]. However, if 'Solarization of Croatia' is realy wanted by the installation of solar systems, it is not possible to achieve it with only part of the stimulus, but the rest of the funds for investment have to be earned with 'Green loans' whose interests should not exceed 3%, as is the case in some European countries. It would be realistic, in Croatia, to be gradually placed, in the next 10 years, 1 m^2 of collector area per capita. This means that the 2020th, in Croatia, could be set around 4,5 million m^2 of collector area, which corresponds to the heat of 30.150 MW.

The Fig. 1 shows the map of Croatian irradiation, with average annual total horizontal surface solar radiation. It shows the total annual irradiation in MWh/m^2, which can serve, with good reliability, for fast, easy selection and calculation of the contribution of solar, photovoltaic systems or solar thermal system for water heating.

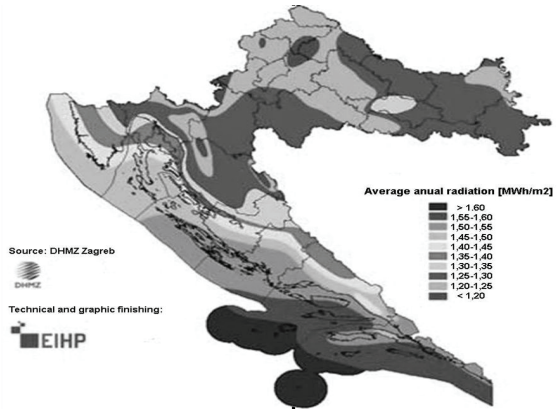

Fig. 1. *Average annual total irradiation of the horizontal surface by solar radiation on the Croatian territory [6]*

Depending on how, and where, the collectors are placed (orientation, tilt, and shading types of assembly) solar contribution to the solar system is changeable.

4.3. Solar thermal system

Solar thermal system is used for collecting radiant solar energy and its conversion into thermal energy, which can then be temporarily stored and used for domestic hot water heating system support. The main components of solar systems for domestic hot water are: solar collector, heat storage, pumping stations, automation and control, and possibly auxiliary heater. Other components of the solar system are flow and return pipeline, a safety valve, expansion tank, gate valves, check valves, pressure gauge, thermometer, safety temperature limiter (if needed), the temperature sensors of the collector and the tank, valves for filling and emptying. Yet the two most important components of the solar system are solar thermal collectors (plate or vacuum type) and heat storage.

The collector is receiver of solar energy and must be designed in a way that allows good collection of solar radiation and good conversion of solar energy into thermal energy. It also must allow good transmission of solar radiation on the power transmitter (solar medium), and simultaneously to minimize disclosure of the heat in the immediate surroundings. The solar collector is insulated box with a viewing side, below which are tubes through which water passes. The tubes are connected to sheets, so called wings that make up the entire interior surface of the collector. The cheaper and less efficient variants of wings are made of aluminum, while more expensive, but more efficient variants, are made of copper.

Wings are painted black to increase amount of received solar radiation that passes through the transparent side of panels. Solar radiation is then converted into thermal energy. This thermal energy is transferred from the metal fins on the tube (because they are physically connected) and heats the water that passes through them. Heated water drains into the tank where heat accumulates. It is important that the tank is well insulated and in warm place because it reduces energy loss.

The most commonly use of this system is for the following purposes:

a. Preparation of hot water

b. Reheating water heating system

c. Warm-up pool water

The preparing of the domestic hot water (DHW) in the average household in the continental part of Croatia takes approximately 20% of total annual consumption of thermal energy, while the rest is spent on space heating (73%) and cooking (7%). In coastal areas the share of energy for DHW is even higher. The average citizen spends a day about 200-300 liters of water, of which an average of 40-80 liters goes to hot water temperature of 40° C to 60°C, which is mainly used for personal hygiene and washing dishes. In a season when there is no heating, preparing a hot water represents the single largest expenditure of energy a household, regardless of the fuel used. Effective preparation and use of DHW, can therefore substantially reduce overall energy costs in the household [7]. Example of solar panel configuration is shown on Fig 2.

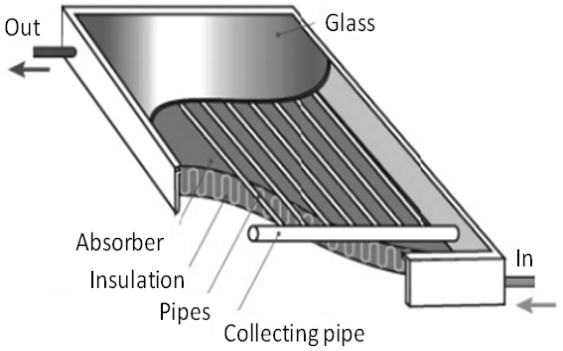

Fig. 2. *Solar panel configuration*

4.4. Solar panel configurator role

Solar energy is the only energy source that belongs to every man and which can be used depending on their needs. It is necessary to show the utilization manner of this energy, in this example, through solar panels, and thus the technical characteristics of the product, its ability to improve and product development. Also, if it is a newly opened company, it is necessary to conduct market analysis to be able to invest in production or to might even think about investing in the product. Given that there are customers, with different requirements and selection criteria, it is necessary to offer more varieties of products to meet the requirements of all customers.

Without the participation of a buyer, manufacturer could not adequately accomplish each individual request. One of the keys to the success of MC is to make quality design tool (configurator) in a way that it does not offer too much choice to the buyer. On the other side, customers do not want the limited choice, that is only offered options, but want their own individual product. The manufacturer must help them to understand exactly what they want. With offered configuration a customer is educated about the specific product in a way that is familiar with the components of the product, and all the ways of connecting parts, which encourages innovation. All manufacturers have already defined some of the offerings, but each customer can choose some of the characteristics of products or add some. The more information, concerning the customer definition of the product, will allow better optimization of the product. After delivery of customized products, the manufacturer may use feedback from the customer for the next period, which ensures faster and easier production. The database is increasing and is updated with each additional purchase. Costumer needs are not constant but they are constantly changing, so the company must take into account the recognition of future consumer needs and to plan future products and services.

Many companies that have achieved great success with software for the MC, were met with great challenges and costs in making the interaction model. Although many companies recognize the huge profits from the software, yet the cost and risk are the barriers to adoption of new software tools. Sales and marketing are focused on the added value of customized products, while engineers are reluctant because of the high risk,

large investments and costs. However, long-term system for the realization of interaction with customers is one of the key factors for cost reduction. Known as configurators, or as co-design platforms, design tools are responsible for guiding the user through the configuration process. Configurator can be defined as a software tool for the implementation of MC strategies, which allows the manufacturer to automatically generate a product-based information requirements set by the user. Development of a high quality system configuration is very important regardless of the level of implementation of the MC. In this way it is possible to process a large number of queries and their forwarding to the production, for the further development and production of non-standard parts. Computer visualization via the configurator is also used as a marketing tool and way of impressing the customer, who are then even more satisfied to buy the product even if the adjustment from previous product in product family is minimal.

Despite large variations configurator consists of three main components:

a. The core configuration software presents possible variations and leads the user through the configuration process by asking questions or leaving the formatting options.
b. Tool for feedback is responsible for representing the configuration. Feedback to design variants can be visualized as a dedicated or in other forms (eg, price information, the test functions, time to deliver) and provides a basis for user learning.
c. Advanced analysis tool translates the customer's final selection to a specific list of materials, construction plans and work plans. Furthermore, the configuration of production can be made or sent to other departments.

The process for developing configurator for mass customization of products is done in several steps:

a. Analysis of the process: The first step which is carried out is analysis of existing conditions in the system, from the standpoint of type and product type, the set of functional requirements of different flows in the system, the level of automation of planning and production management.
b. Analysis of the product: The analysis of the product for an additional life cycle analysis, determine the need for adaptation and implementation of the desired concept in terms of redesigning the structure of a complex product.
c. Object-oriented analysis: This step is concerned with forming groups which are operating within the structure of a complex product with a parameterization of the representative of each product group.
d. Object-oriented design: It is choosing software configurator and considers linking product models with other existing systems, designing, and planning and production management.
e. Programming: Programming configurator based on product model defined. Test Configurator.
f. Implementation: Implementation of a product configurator for the organization's enterprise system. Training and instruction of employees who are directly involved and connected with the system configuration of the product.
g. Maintenance: Maintenance and further development of products and systems have to be constantly adjusted to changes in the product and its components.

4.5. Configurator features

Advancing technology increases the number of solar collectors and components from which they were made, and with increasing diversity, the possibility of their choosing is increased. In this paper, using the "Visual Studio Development", one of the possible ways to configure the collectors is presented, in order to achieve the best possible satisfaction of the individual customer. Each customer, under his user account, has the ability to configure their own products. Previous method, where the promotion of the availability of solar collectors is mostly limited to the catalogs with pre-defined characteristics and prices may satisfy a portion of the market, in which, the offered products meet the needs of the market. The user friendly interface, which is easy to reach from company promotion web page, is shown on Fig. 3. It starts with login into account for customer, or login into account administration for company employee.

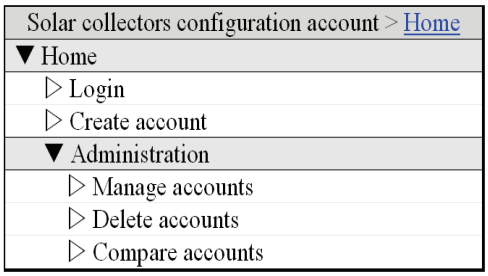

Fig. 3. *Window for log in the account*

However, each purchased unit has different conditions to work in, and therefore heat loss, which leads to different dimensions and the required efficiency of solar collectors, and therefore different prices. This configurator provides an opportunity, for buyers who know exactly what they want, to construct a solar collector in a manner that will optimize their requirements. For each component, they have the option of choosing between multiple versions of each component and by selecting they create their own configuration. On Fig. 4 it is shown the glass selection page with types of glasses which are available for installation on panel. It shows all necessary data about glass material, and price per square meter. On right side of Fig. 4. it is shown illustration with empty fields which have to be fulfilled to finish configuration definition.

Create configuration > Glass	ID	Type	Thic-kness	Weight [kg/m²]	Trns. coef.	Max temp. [°C]	Price [HRK]	Choice
▼ Home	1-O	Ordinary glass	3	10,0	0,84	160	120	Choose
▷ Solar panel configuration	2-TF	Tempered with low Fe	4	10,0	0,91	200	200	Choose
▼ Create configuration	3-P1	Polycarbonate	4	4,9	0,80	130	250	Choose
▷ Dimensions	4-P2	Polycarbonate, double	16	1,2	0,80	130	320	Choose
▷ Inclination	5-PC	Polycarbonate, capillary	10	0,14	0,69	130	400	Choose
▷ Casing	6-PM	Polycarbonate, meshed	10	1,7	0,75	130	420	Choose
▷ Insulation	7-A1	Acrylic	4	4,8	0,84	90	350	Choose
▷ Absorber	8-A2	Acrylic, double	16	5,0	0,77	90	460	Choose
▷ Pipes	9-A3	Acrylic, triple	16	5,6	0,72	90	520	Choose
▶ Glass	10-PT	PTFE Teflon	8	0,12	0,96	200	470	Choose
▷ Sealing								
▷ Save configuration								
▼ Modify configuration								
▼ Delete configuration								
▼ Pipeline system								
▼ Fittings and equipment								

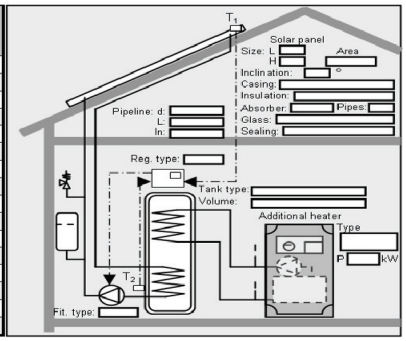

Fig. 4. *Window for glass selection and illustration of current configuration*

Users, by creating their own accounts, have the option of configuring their own collectors. This creates a special feeling for the customer, and also, the company produces a database of individual customers. Of course, if the user does not correspond to the materials that are offered to individual components, he has the ability to input his own suggestions. If the material is considered unprofitable for the company, and the number of configurations there is a need for it is too small, it will be rejected. But it will certainly have an impact on further supply of the company. If the demand for certain components, dimensions or material, are significantly higher, a company could have such products in stock to be able to respond to the request in the shorter lead time. That is not entirely consistent with the concept of mass customization of products, but mass customization and its application in reality in full content is still impossible.

If there are buyers who do not know exactly what type of collectors, and its features they want, and they do not want to go through the configuration process, because they are not familiar with terms and data from configurator, a special offer can be made for them. By developing a brief survey up to 10 questions, the opportunity to define the necessary specifications is given to the user. By using its own database, company could offer to the user, quickly and efficiently, several types of solar collectors to match his request. It also opens the possibility of choosing solar panels for customers who are not sure that the solar collector can meet their needs. These customers may be allowed, by answering to these questions, based on a software program, to get calculation of the required area of solar collectors as a feedback. Such calculations are required when customer has not already defined the necessary values, to avoid the inconveniences that are results of buying collectors randomly. On Fig. 5 there is example of such a survey for domestic hot water.

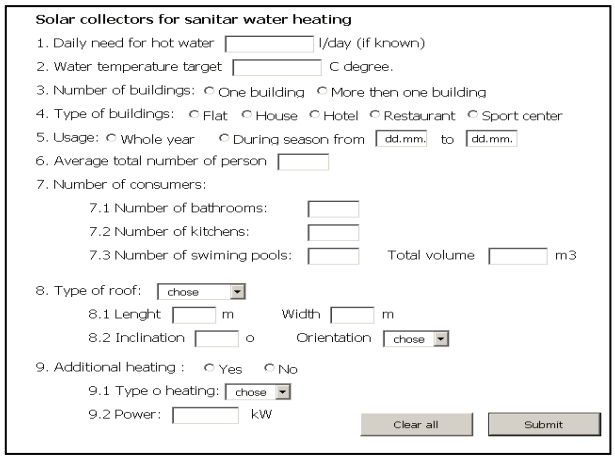

Fig. 5. *Survey for configuration request*

4.6. Company feedback on configuration request

In this phase of development, presented configurator is able to immediately estimate total costs of raw material parts and semi products which are supplied from upstream companies in supply chain. For estimation of production costs, production processes data, about expenses of human work, machine work, tools, amortizations and all fixed costs should be applied. It is very demanding to implement due to requisite that design, construction and production technology department should prepare all documentation regarding to requested configuration. To some extent, it could be resolved with experience data in recent production period.

One of most important thing concerned with customer satisfaction with company's offer is time necessary for delivery of ordered configuration. Time estimations which are randomly set by producer are often incorrect, and they are playing a big role in company reputation. On one side, longer period to supply then necessary can make potential customer to choose another company, and on the other side, longer period for delivery then estimated, can make a customer very angry and disappointed. In internet era, market globalization and extensive information sharing, not only among professional networks, but also on social networks, angry customers can make big impact on company survival.

Due to reasons listed above, larger amount of effort should be directed to calculation of time necessary to fulfill every customer demand. Therefore, it is necessary to collect all necessary information, form shop floor, inventory storages, purchasing department and also from availability of raw materials upstream of supply chain.

With the flexibility of production, the vast majority of manufacturing systems have not reached a degree of flexibility demanded by MC systems, including Lean manufacturing which will be implemented in solar panel manufacturer. Lean manufacturing is based on the adaptation of each operation and it works if the demand for the product is stable. In Lean manufacturing, the company aims to cut all costs which are not directly related to the production of a product for the consumer. In an environment of high and stable levels of demand, it is a very effective organizational method. The scientists from prestigious American universities have defined five Lean principles for managing production based on Lean production [8 and 9]. First of them is closely related to understanding what the customer wants to buy and providing full service to satisfy customer. This principle emphasizes the importance of production of product which will be valued by the customer and for which the

customer is willing to pay. This principle also explains the importance of removing the waste from the processes. Waste is considered as any activity in production system which stops or extends process of transforming material or information into money.

On the other hand, Agile manufacturing philosophy resolves disadvantage of Lean manufacturing concerned to product stable market demand. It is a term applied to an organization that has created the processes, tools, and training to enable it to respond quickly to customer needs and market changes while still controlling costs and quality [10]. It is often seen as the next step after Lean manufacturing in the evolution of production methodology. Due to its manufacturing philosophy, it requires working out of stock, so any downtimes or any unforeseen breakdown can cause disrespect of deadlines and customer dissatisfaction.

Both philosophies are hard to implement in full extent in any of production system, including solar panel manufacturer. Value Stream Mapping (VSM), one of Lean manufacturing tools, can be applied in this production process to visualize production flow, including stock levels, process cycle times and product lead time. VSM calculations are able to estimate total process and waiting time of all parts, to find a bottleneck process, or to find parts that need the most amount of time to be supplied. According to this it is possible to estimate time for delivery to final customer, and therefore calculate total costs and availability of production plant for another customer.

On the other hand management of supply chain is also a key factor in achieving success MC. It is responsible for interacting with purchase department, supply of customized products, manufacturing and procurement of materials from suppliers. The success of supply chain management plays an important role in achieving goals such as lower costs and shorter delivery time and largely depends on the communications infrastructure.

5. CONCLUSION

The usefulness of solar energy, and the availability of the solar collectors on the market, adjusted by price and technical characteristics to the individual customer, is the main topic of this paper. Using solar energy does not have any adverse impact on nature and man, and the great advantage is that it is free. Paper shows the concept of product configurator which enables customer to choose between large numbers of possibilities. It gives customer freedom to, without influence of company employee knowledge, configure its own product. Feedback from company could include costs of material and production process, as well as possible time to supply. As there is need for large amount of data, concerning current state in production shop floor and raw material availability along whole supply chain, it needs some time that feedback to customer could be sent. Future work will be related to achieving higher level of automation of calculation of feedback information. On the other side, more dynamic production planning according Lean manufacturing principles will be made to planed state of production process, before decision about start of production process.

6. REFERENCES

[1] F. Salvador, P. Martin de Holan, F. T. Piller, "Cracking the code of MC", MIT Sloan management review, Vol. 50, No. 3, Apr. 2009, pp. 71-78.

[2] M. Sosa, E. Eppinger, D. Steven; C. M. Rowles,: "A Network Approach to Define Modularity of Components in Complex Products", Journal of Mechanical design, Vol.129, No. 11, 2007

[3] K. A. Kamran, M. S. Salhieh, "Product Design for Modularity", Kluwer Academic Publishers, New York, 2002.

[4] D. Pavlić, "Sustav za konfiguriranje proizvoda modularne arhitekture", Master thesis, Zagreb (CRO), 2003, pp.5-14. (in croatian).

[5] HSUSE, "Solarizacija Republike Hrvatske, 2. dio", članak Hrvatske stručna udruga za Sunčevu energiju, Zagreb, 2011. (in croatian).

[6] HSUSE, "Energija Sunca - potencijali, tehnologija, stanje tržišta", Hrvatska stručna udruga za Sunčevu energiju, Zagreb, 2010. (in croatian).

[7] D. Dović, "Sunčani toplovodni sustavi", handbook, Secondary technical school Ruđer Bošković, Zagreb, 2010. (in croatian).

[8] J. P. Womack, D. T. Jones, D. Roos, "The Machine that Changes the World: The Story of Lean production", HarperCollins Publishers, New York, 1990.

[9] J. K. Liker, "The Toyota way 14 management principles from the world's greatest manufacturer", McGraw-Hill, New York, 2004.

[10] L. Goldman, R.L. Nagel, K. Preiss, "Agile Competitors and Virtual Organizations - Strategies for Enriching the Customer", Van Nostrand Reinhold, New York, 1995.

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