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APPLYING A SOLID MODELER TO BRING SUSTAINABILITY THEMES BEFORE SME REPRESENTATIVES

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Abstract. *Sustainability themes are gradually gaining importance among companies and industrial designers in the region of Western Balkans. Nevertheless, sustainability principles are yet to be acquired by many working professionals, and many engineering training programs should be enriched by environmental science related courses. There is a constant need for new approaches and tools that are convenient for refreshment courses and trainings. Appraisal of Environmental impact of a product relies on adequate software tools that allow for initial screening, and with graphic user interface that fits users' capabilities. There are several software packages and databases designed for Life Cycle Assessment (LCA), but rather few of them are integrated with Computer Aided Design (CAD) systems in a consistent manner. Spreading the life cycle approach among young engineers and working professionals would require user friendly software tools suitable for promoting environmental friendliness. This paper brings about impressions on training-friendly features of a LCA-enriched CAD modeler and its suitability for explaining fundamentals of sustainability to representatives of Small- and Medium-sized Enterprises (SME).*

Key words: *Sustainability Education, LCA, CAD, Ecodesign, SME*

1. INTRODUCTION

The United Nations Decade of Education for Sustainable Development that was announced in 2005 gave impetus for environmental related curricula development on a global scale. Ever since, original educational approaches and teaching aids have been regularly adapted to serve sustainability goals. The combined efforts of the academia and industry have risen environmental and sustainability issues to the point of widest recognition. Product designers trained in environmental subjects are steadily being sought by the progressive companies.

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The World Business Council for Sustainable Development predicts that, by the year 2030, there will have been 3 times more middle class consumers in the developing world [1]. One such development would, by no means, radically increase consumption of goods and services. The only way out would be to build environmentally friendly products through ecodesign. This endeavor would require well educated, environmentally conscious engineers and designers. Conventionally, engineering education has been framed in specific areas and taught through approaches that focus on technical performance, economical procedures and energy efficiency. Almost decade ago researchers from Latin America and Europe created "curriculum greening", a model for implementing sustainability principles in higher education. Among other features, the model called for the following requirements regarding the environmental education of engineers [2]:

- integrating complexity in the curriculum (analysis of causes and effects of environmental problems from a systemic point of view);
- establishing coherence and interaction between theory and practice;
- adapting new teaching and learning methodologies, based on participation and problem solving.

The implementation of "curriculum greening" allowed for dissemination of knowledge on sustainable development in diverse environments, globally [3]. Since then, both the model and the approach in teaching engineers "applied sustainability" has gradually changed. Education has become a life-long process, and it particularly holds for education for sustainable development that comprises both formal and all other forms of education. Environmental issues would be addressed in an adequate manner only by designers and engineers whose professional competencies have been gained through appropriate, tailor-made courses [4]. Environmental related curricula for diverse engineers has to be developed in such a manner, to give both educators and their students enough room for exploring latest tools and techniques, and thus let them fully benefit from novel approaches in teaching sustainability.

Modern manufacturers from the developed world regularly incorporate sustainability into their design. Sustainability assessment is often performed through a comprehensive life cycle analysis, including end-of-life scenario analyses, applying various models and metrics to quantify the environmental impacts [5]. Comparing the eco-features of products has become progressively widespread [6].

However, in order to achieve sustainability goals, entire design process should be reconsidered to integrate environmental concern and the elements of corporate social responsibility [7]. In a previous research aimed to depict the state of play in the use of life cycle management (LCM) among small and medium enterprises (SMEs) in Western Balkans, it has been noticed that the most frequently applied measures were those that could be easily translated into reduction of costs, so that "LCM/LCA and eco-design top the list of seldom applied environmental measures among the SMEs analyzed" [8].

Many authors have recognized necessity to integrate sustainability into the existing courses of various engineering programs [9]. Sustainability is traditionally taught more in a few engineering disciplines such as environmental, civil and chemical engineering [10].

Incorporation of sustainability themes in engineering courses is essential to make the working professionals understand the environmental implications of contemporary technologies, and to make them incorporate environmental friendliness into their designs [11]. Several authors have investigated integration of CAD and life cycle inventory as one of the viable approaches aimed to support ecodesign [12], [13], [14]. It has been emphasized that CAD relies on feature based modeling which comprises structural information of the design

itself, while LCA data (mostly related to materials and processes) are used to estimate a range of environmental impacts.

Growing awareness and importance of sustainability has obviously motivated certain CAD software producers to couple up efforts with LCA software companies, and subsequently launch suitable modules capable to perform real time LCA analysis. Inventor by AutoDesk included appropriate features in partnership with Sustainable Minds [14]. The LCA was performed on Bills of Materials derived from CAD. Even more compact is SolidWorks Sustainability by Dassault Systems that was launched in 2010 (upon integration of Sustainability Xpress module with extended capabilities into the standard CAD package). The module allows designers to perform streamlined LCA on their CAD models in real time [15]. Morbidoni and colleagues described capabilities and features of CAD based sustainability modules in detail [13]. SolidWorksTM Sustainability (by Dassault SystemsTM) and GaBiTM (by thinkstepTM) have been taken as reference packages of a kind.

2. METHOD

2.1. Application of a CAD/LCA tool

The sustainability module in SolidWorks allows for selecting the materials, manufacturing processes and transport means early in design process. The module covers a wide range of product features and design criteria [16]. It puts the designer in position to perform a Life Cycle Assessment (LCA) of the products within the SolidWorks graphic interface. LCA reveals the consumption of materials and energy, as well as the emissions to environmental compartments that occur over the entire life cycle of a product.

A short course was organized in such a manner that it provided a basic exposure to frequently used engineering materials and industrial processes, even when the most of the participants did not have broad knowledge about CAD systems. Trainees acquired information on the structure of the sustainability module and jointly performed the sustainability analyses under the direction of the trainer. Since the training was oriented toward “freshman in sustainability” the aim was not to deliver typical software module usage course. The emphasis was on explaining what sustainability is all about in engineering environment. However, it is expected that once the trainees have learned about materials and manufacturing processes, they will gradually become capable to assess a product’s sustainability on their own.

SolidWorks possess a module fully equipped for pre-manufacturing appraisal of environmental impacts during the product development process [16]. The sustainability module enabled a trainee to compare environmental impacts of different materials and perform a comparative analysis during the design process. It also generated so-called Sustainability Report that disclosed environmental impacts of a product with all relevant details. The module extracts data from built-in database by thinkstepTM, a renowned producer of an industry standard for LCA, the GaBi software. It should be noted that the database is not meant to provide full LCA, but the module allows designer to search for improvements in the environmental impacts and to design away sustainability conflicts whenever possible. Extraordinary features of SolidWorks allow for efficient file transfer, while material selection feature refers to a designed assembly and creates a Bill of Materials.

Not meaningless for the trainees in emerging economies is the fact that the sustainability module comes free of charge with the SolidWorks academic license.

The following input parameters are required for environmental analysis of an assembly: material and manufacturing process selection, manufacturing facility location, and the location of a product use. Participants were invited to assist instructor in defining input parameters. Firstly, they had to choose from wide range of engineering materials available. The trainer helped them to focus on frequently used technical material such as steel, aluminum, plastic, and rubber (Figure 1).

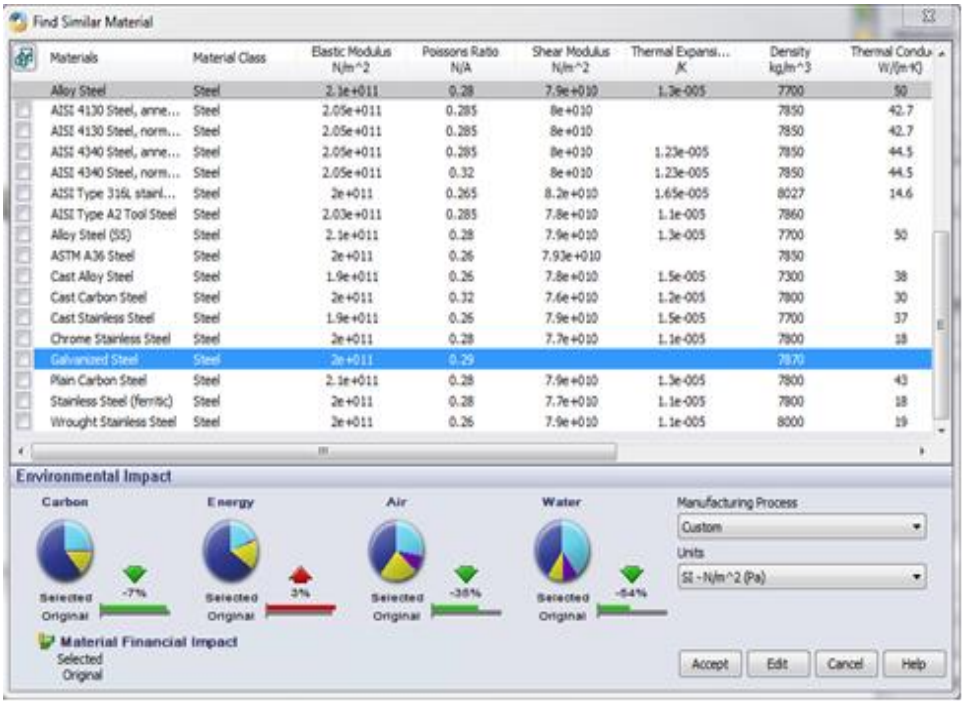

Fig. 1 Environmental impact change after substitution with a similar material

This is the point when sustainability awareness comes out from hands-on experience, since the impact of material on the environment becomes visible in the sustainability report (Figure 2), where the contribution to the environmental impact in every phase of a life cycle is presented in the form of a pie graph or a bar chart. For comparative studies, there is also possibility to set a baseline and thus monitor progress. The module comprises the following key indicators: energy consumption, acidification, eutrophication and carbon-dioxide emission. It also takes into account transportation impacts (based on distance and transportation means).

Fig. 2 Environmental impact comparison in a typical Sustainability Report

Upon getting acquainted with the structure and the main features of the module, participants were asked to take part in a case study. Due to very diverse experiences with CAD systems among participants, and limited time devoted to environmental sustainability in the program, the modeling phase was omitted. Therefore, participants had to rely on imported model that consisted of a few parts made of just two or three diverse materials. This way participants were able to focus their attention on sustainability analysis principles. A couple of 3D models applied are shown in Figure 3.

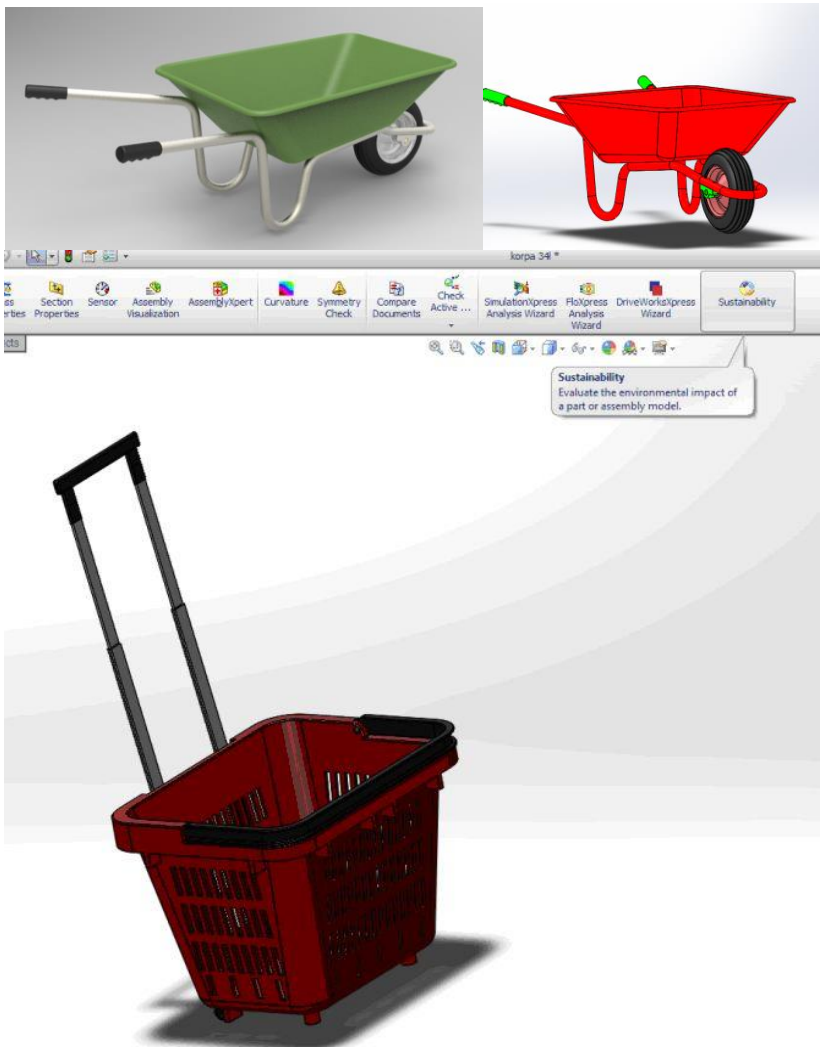

Fig 3 A couple of three-material solid models applied for the training

With constant assistance provided by instructor, participants selected materials, manufacturing processes and regions of manufacturing and use. All the indicators of environmental impacts comprise the impacts caused by material, manufacturing, use, and end of life treatment. At the bottom of each chart, the total amounts of individual impacts are presented. The report that was generated by the module was self-explanatory with summaries and important details.

Afterwards, participants were called to perform a comparative study by changing materials (e.g. aluminum, steel or ABS), processes (e.g. extrusion or injection molding) and locations (Europe, Asia). The comparison option is of particular importance for sustainability

teaching since it reveals obvious impacts of different options and facilitate the identification of favorable solutions. Having performed sustainability assessment of a few widely used materials and manufacturing processes, the trainees were called to derive relevant conclusions. For instance, after having opted for certain materials, they were advised to pay attention to how energy intensive aluminum was, and how much emission of carbon-dioxide consequently increased.

After the training, the participants were given a brief control test with two basic questions in order to somewhat objectively reveal the level of acquired knowledge:

- When and how do the products create environmental impacts?
- What are the indicators used to measure the environmental impacts?

2.2. The survey

A survey was designed in the framework of a wider study with the intention to collect preliminary information on the subject. A questionnaire was distributed to 90 engineers, mostly from manufacturing SMEs that operate the region. Data was collected between last week of January and the end of February 2015 via the survey method using a questionnaire to reveal the opinions of respondents. The questionnaire of the same contents was administered to respondents before and after course sessions.

The questionnaire was intended to measure the degree of comprehension of sustainability and effectiveness of using CAD/LCA tool to teach sustainability. The main goal of this survey was to test the general familiarity with sustainability concept after applying specific software tool (i.e. CAD platform) for teaching engineers from local SMEs. The pilot research was directed toward the following research questions, with no ambition to finally resolve them, but to trace the route for some similar, comprehensive research of larger scale:

– Are the CAD/LCA packages, such as SW Sustainability, appropriate for teaching sustainability related courses for engineers regardless of their background?
– Would those packages with their visualization features increase understanding of benefits that sustainable design might bring to a company and the society?

The questionnaire was divided into three main sections: company data, respondent data, and sustainability. The company data section comprised the information such as industrial sector, number of employees and position in supply chain. The respondent data section included respondent's level of education, educational background, previous courses with sustainability contents, and familiarity with CAD packages.

The section entitled sustainability comprised 4 questions with various predefined answers to be given a priority rank from 1 (least preferable) to 3 (the most preferable). The questions intended to provide answers in the following subject areas (as perceived by the respondent):

- Self-Assessment (How would you assess your understanding of sustainability concept?)
- Relevance (Do you find sustainable design important for industry and society?)
- Applicability (Do you find sustainability concept applicable to your company?)
- Motivation / Willingness to acquire knowledge (Would you continue to attend sustainability and/or environmentally related courses?)

Being pioneer survey of a kind, this study was not intended to be a statistically representative. The main purpose was to get insight into the perception of sustainability among representatives of regional SMEs, and to assess suitability of the chosen tool for the purpose.

3. RESULTS AND DISCUSSION

The research was conducted with representatives of SMEs form South-East Serbia that attended various refreshment courses for young engineers and technicians. All the administered questionnaires (90 in total) were completed during the courses, so the response rate was 100%. The sample size is rather small, but sufficient to generate some meaningful statistical results.

Most of the respondents (almost 57%) came from small businesses with up to 50 employees, medium-sized firms employing between 50 and 250 persons were represented by nearly 32% participants, while the rest came from micro-enterprises with less than 10 employees (Figure 4). It has to be emphasized that the participants were mostly from manufacturing companies, with a few exemptions when representatives came from engineering service providing companies or consultancies. Unusually, larger companies were underrepresented although those often possess qualified workforce to deal with environmentally related issues, and therefore readily participate in refreshment courses of a kind.

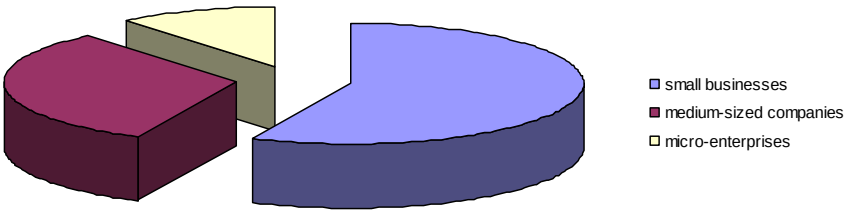

Fig. 4 Participants' SMEs, per size

It is obvious that the post-training increase in all 4 categories examined (value "high" at 3-point scale (Figure 5.)) was made mostly at expense of the group of participants that subscribed to "average", except for self-assessment category, where "average" group of participants actually increased after training. However, this fact also reflects significant decrease in the number of participants that self-declared "low" understanding of the concept before the training. It might also indicate that the participants were rather precarious and/or objective under self-assessment, both before and after the training.

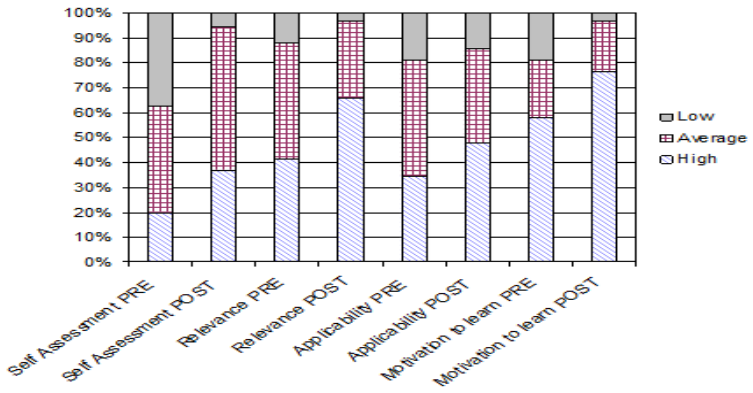

Fig. 5 Pre- and Post-Test Assessment

According to the weighted average values, the best progress was achieved in understanding sustainability concept. The increase in the Self-Assessment category (understanding, as perceived by the trainees) was almost 27% after the training, followed by perceived relevance of sustainability for industry and society (14,5% increase) (Table 1). However, mere 8.3% increase in recognizing applicability of the concept in the home companies of the participants suggest that both course contents and the models applied have to be tailor-made and carefully prepared beforehand.

Table 1 Compliance by a 3-point scale (as a weighted average) across the categories: 1-low; 2-average; 3 high

	SelfAssessment	Relevance	Applicability	Motivation
Pre-training	1,708	2,146	2,021	2,24
Post-training	2,167	2,458	2,188	2,563
Increase in category (%)	26,874	14,539	8,263	14,42

Given the purpose of the study, it was interesting to find out if there were any dependencies between certain trends that could help derive preliminary conclusions for a further research. The data were subjected to descriptive, summary statistics by SigmaStat 3.5 statistic software. In order to find out whether the medians of two different samples are significantly different, The Mann–Whitney rank sum test was performed (Table 2).

Table 2 Mann–Whitney test

Dependence tested	Criteria	Mann–Whitney rank sum test result
Are the participants that previously attended sustainability related trainings more prone to recognize applicability of sustainable product design in their respective companies?	Declared previous attendance at sustainability related trainings vs. declared recognition of sustainability concept applicability	The difference in the median values between the groups is greater than what would be expected by chance; there is a statistically significant difference ($P = 0.032$) $P < 0.05$.
Is there dependence between a participant's level of education and willingness to take further training in sustainability and the environment?	Declared level of education vs. willingness to take training (average and above)	The difference in the median values between the groups is greater than would be expected by chance; there is a statistically significant difference ($P = 0.018$) $P < 0.05$.
Is there dependence between a declared familiarity with a CAD system and learning outcome as perceived?	Declared above average experience with a CAD system vs. perceived progress in sustainability comprehension	The difference in the median values between the groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference ($P = 0.128$) $P > 0.05$.

The above results suggest that a lack of previous experience with CAD software doesn't necessary mean less successful outcome of the training. This fact might indicate user friendliness, good visualization features and other qualities that SolidWorks Sustainability possesses for the given purpose.

In order to validate preliminary findings, a more extensive survey is needed. A large scale survey could also reveal the new dependencies that are important for a custom designed program of training. Therefore, several information sessions should be organized for diverse industrial sectors and in particular for SMEs of various sizes.

4. LESSONS LEARNED

Each topic should comprise a structured training plan and relevant supporting materials. The lessons should be interactive, including discussions and critical thinking rehearsals. Each of the trainings should include background information on the topic, objectives, available methods for problem solving, and relevant case studies. Simple assignments have proven to be a good way to make the participants acquainted with the core subject. One such approach should always be enhanced by hands-on experience, using appropriate software tools and databases. Engineers prefer to obtain what they perceive as a customized program adapted to their objectives. It is still needed to forward sustainability oriented thinking to regional SMEs. Due to limited time available for trainings, monomaterial, bimaterial or maximum three-material models should be analyzed during the sessions.

In order to evaluate these preliminary findings, a more comprehensive survey is obviously needed. A series of tailor-made courses should be arranged for SMEs from various industrial sectors. The main goal would be to motivate SMEs to choose a green path. Environmental issues are of great importance for transition countries trying to improve resource efficiency in accordance with EU policies.

6. CONCLUSION

The quality of life depends on environmental impact of commonly used goods, services and processes, all of which should be designed in a sustainable manner by environmentally conscious engineers. Contemporary training programs should provide modern engineers with knowledge rather than just with skills, in order to enable them to take part in greening the industrial development. Technology skills are obviously important but, by no means, they should be fostered at expense of understanding the environmental and ethical issues.

Quality education on professional level would significantly support the development of new values among designers and engineers. This, in turn, would ultimately lead toward a new model of behavior in companies, industrial sectors and in society as a whole.

The module Sustainability of SolidWorks was applied for the tailor made course targeted at engineers from SMEs. Learning success of the participants was assessed and results obtained indicate a significant improvement in sustainability comprehension. Combining LCA with CAD provided good results for engineers of different backgrounds. Addition of sustainability themes into continuing education courses seemed to pose a challenge for participants and trainers alike, but user friendly features in SolidWorks Sustainability allowed for making progress in reasonable amount of time. Integrating environmental concern into the continuing education courses for engineers is of great importance, since the representatives of

SMEs have to understand sustainability and must be prepared to design eco-friendly products from scratch. It seems that SolidWorks is an appropriate tool to teach the fundamentals of sustainable engineering and life cycle assessment. A more comprehensive study of SolidWorks Sustainability applicability for teaching ecodesign principles might be extended to other programs of larger scale, aimed to SMEs from various industrial sectors.

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PRIMENA CAD MODELERA ZA PREDSTAVLJANJE SADRŽAJA O ODRŽIVOM PROJEKTOVANJU PREDSTAVNICIMA MALIH I SREDNJIH PREDUZEĆA

Teme iz domena održivog projektovanja postepeno dobijaju na značaju u kompanijama i među projektantima u regionu Zapadnog Balkana. Međutim, principi održivosti tek treba da budu usvojeni od strane mnogih profesionalaca u industriji, dok programe obuke inženjera treba obogatiti sadržajima kojima se bavi nauka o životnoj sredini. Postoji stalna potreba za razvojem novih pristupa i alata koji su pogodni za kurseve i obuke namenjene zaposlenima u industriji. Procena uticaja proizvoda na životnu sredinu zasniva se na upotrebi odgovarajućih softverskih paketa čiji grafički korisnički interfejs odgovara mogućnostima i potrebama korisnika. Postoji više softverskih alata koji su namenjeni analizi životnog ciklusa proizvoda (LCA), ali je još relativno malo onih koji su uspešno integrisani u savremene CAD sisteme. Diseminacija principa sagledavanja životnog ciklusa među mladim inženjerima i iskusnim profesionalcima zahteva pogodne softverske alate kojima se koncept održivosti može promovisati na odgovarajući način. U ovom radu, prikazana su iskustva u primeni jednog naprednog CAD sistema koji sadrži odgovarajuće LCA module i pruža obilje pogodnosti za predstavljanje osnova održivog projektovanja predstavnicima malih i srednjih preduzeća (MSP).

Ključne reči: *održivo projektovanje, LCA, CAD, ekodizajn, SME*