Lifelong Learning in Learning Factory

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Abstract

The aim of this paper was to present a detail analysis of manufacturing processes using Case study of Croatian manufacturing industry. Therefore, conducted analysis showed that Croatian manufacturing enterprises are far away from fourth industrial generation. Moreover, the importance for personnel’s education, i.e. lifelong learning, has been identified. For that purpose, Learning Factory on FESB at University of Split, has been established. For lifelong learning activities, a specialized educational platform, developed in EU Leonardo da Vinci project LOPEC, was used. In this paper, lifelong learning concept based on e-learning platform and self-assessment module of project LOPEC has been presented.

Keywords: Lean Management, Lifelong Learning, Learning Factory

Introduction

Half a decade of global economic crisis had a significant impact on European economy, especially on European manufacturing industry. The dramatic drop in customer demand has led to reduced working hours, layoffs of workers and idle factories. The situation has been even worse in weaker economies, like Croatian economy (Bezic et al., 2011). This paper focuses on case study of Croatian manufacturing enterprises, which are cornerstone of Croatian economy.

Croatian economy is still burdened by previous economic system inherited anomalies and some transitional problems. Low productivity is additionally burdened by a great number of employees and obsolete technology. Insufficiently educated and unskilled personnel, particularly in the production and management fields, are decreasing competitiveness necessary for survival in the global market (Veza et al., 2013). There is a predominant lack of products and services which are demanded by developed markets. Grey economy is growing, encouraged by infirm justice and unstable tax administering during recent years. However, public property and enterprises privatization, which is a sine qua non
prerequisite for sound market basis establishment and prospective growth, has not been successfully implemented. Most public enterprises completely disappeared in the privatization process, and those that managed to survive, have undergone numerous recovery programs or have gone into liquidation. In these conditions, small and medium-sized enterprises development could not have support by big industrial systems. Therefore, economic development has been mostly turned to the service sector, especially tourism.

The lack of a unique and commonly agreed economic strategy is present at the national level. One of the primary strategic goals is to develop a competitive, diversified, technologically advanced and environmentally sustainable economy that will be oriented to enhance the living standard of the local population. Consequently, such clearly defined goals require a radical change of the existing settings, in which an inadequately competitive economy still prevails.

The main question is how to detect competitive advantages of the manufacturing industry and therefore achieve a higher level of export competitiveness in the regional and the international markets, like the market of the European Union (Veza et al., 2013). Croatia’s manufacturing industry participates by a large proportion in the gross domestic product, employing a majority of the entire workforce. This is one of the greatest generators of tax revenues in the country, and is one of the most propulsive export industrial branches of the economy of the Republic of Croatia (Bezic et al., 2011). Generally speaking, during the transition process, there was no industrial development whatsoever, particularly lacking in new technologies or new products introduction. Cooperation between economy and science was rather weak, and the accompanying infrastructure required to support technological development and innovations, was developing rather sluggishly. Taking all this into consideration, a basic prerequisite for making a turnaround to a successful economic development in Croatia is to restructure its economy.

In order to set things in motion, the following priorities have been defined:

- to strengthen cooperation between research institutions and entrepreneurship that will enable new technologies implementation and technologically innovative products production,
- to restructure organization in traditional manufacturing sectors, agriculture, fishing industry and tourism, in order to achieve bigger competitiveness,
- to support export-oriented, specialized production of products and services with higher added value,
- to encourage regional and inter-regional integration processes (including transnational ones) and to support cluster organizations in order to strengthen overall synergetic impact in the sectors and between them,
- to ensure business, entrepreneurial and managing training,
- to increase employment opportunities.

In near future, the main aims for Croatian enterprise will be flexibility, agility and scalability, in order to survive turbulences caused by erratic customer behaviour and market turbulences on a large scale.

**Innovative Smart Enterprise project**

Croatian Science Foundation (CSF) is financing the project Innovative Smart Enterprise (INSENT) according to the priority to strengthen cooperation between research institutions and entrepreneurship.

Manufacturing enterprises are in the main focus of this project. Vision of Innovative Smart Enterprise for with long term sustainability can be summarized into following

The main objective of this project is to develop Croatian model of Innovative Smart Enterprise (HR-ISE model). The aim is to develop model for regional fit, i.e. to harmonize Innovative Smart Enterprise model with specific regional way of thinking, manufacturing and organizational tradition and specific education. Its results should help Croatian enterprises to bridge the gap between their competencies and EU enterprises competencies and capabilities. Following objectives are crucial to achieve main objective of this project:

- **Objective 1**: It is important to perform a profound research to describe the current state of the Croatian manufacturing enterprise. It will be done by questionnaires and interviews with CEOs and/or technical directors of manufacturing enterprises in Croatia. The aim is to gather the data from as many enterprises as possible. After that, the analysis will be performed to describe the current state of the Croatian manufacturing enterprise. It will be the answer to the question: “Where are we?”

- **Objective 2**: A synthesis of analysis of Croatian manufacturing enterprises will be done through development of Croatian model of Innovative Smart Enterprise (HR-ISE model). HR-ISE model will not be based just on State-of-the-art theoretical models, but also on State-of-the-art practical models like Lean Management philosophy from Toyota Production System. A special effort will be made to bridge the cultural and mentality gaps between State-of-the-art models and current Croatian model. It will be the answer on the question: “Where do we want to be?”

- **Objective 3**: A special learning environment will be established in one Laboratory. It will be a Learning Factory, i.e. simulation of a real factory through specialized equipment. Laboratory will be organized in order to simulate factory based on HR-ISE model. Hence, Laboratory will be learning environment not just for students but also for engineers from manufacturing enterprises. It will be a place in which transfer of developed HR-ISE model to the economy subjects will be achieved. All necessary supporting material and equipment for learning the selected methods and tools will be provided. It will be the answer on the question: “How can we get there?”

The results of this project could be of high value for competitiveness of Croatian industry. The development of Croatian model of Innovative Smart Enterprise (HR-ISE model) and its transfer to economy could have a significant impact on recovery of Croatian industry. HR-ISE model could help improve competencies and capabilities of Croatian enterprises to make them more competitive on EU market.

**Analysis of current state of Croatian manufacturing enterprises**

The Project INSENT wants to improve the scientific understanding of the Croatian manufacturing enterprise by promoting the empirical, enterprise-level research on technological and non-technological process and organizational innovation. The technological and non-technological process and the organizational innovation include the introduction of new production technologies, the level of ICT integration with processes, new organizational concepts in production such as group work or relocation of production, and also new products that emerge from the process and organizational innovation, such as product-related services.
In order to obtain a maturity level of Croatian industrial enterprises, a specialized methodology has been established. It consisted of a profound literature review, questionnaires and visits with interviews being done. The literature review was a foundation for the design of questionnaires for Web and for visits (Figure 1).

**Figure 1 – Methodology for obtaining maturity level of Croatian industrial enterprises**

*Analysis of Web questionnaire responses*

The Web questionnaire has been sent to more than 1980 industrial enterprises. Database “Biznet.hr” of Croatian Chamber of Economy was used. The sample of 8% of total, representing 161 enterprises, has been gathered. Taking into account the enterprise size and geographical coverage and industrial sectors coverage, the sample can be considered as a representative one.

Besides the basic questions about the enterprise itself, a set of nine questions was given, that represent the most important aspects of manufacturing as follows: Product Development, Technology, Work Orders Management System, Production Traceability Monitoring, Materials Inventory Management, Stocks of Finished Products Management, Quality Assurance, Product Lifecycle Management, and Application of Toyota Production System and Green and Lean Production Concept.

Each answer was converted to a score from 1 to 4 representing one of the four historical industrial generations (Kagermann et al., 2013). For instance, work order management based on oral communication between employees belongs to the first industrial generation and its score is 1.0. However, work order management based on communication man to machine belongs to the third industrial generation and its score is 3.0. It was possible to select more than one answer to each question. Depending on the selected answer(s), an overall score for each question was calculated as an average value of all selected answers and their scores (Figure 2).
Figure 2 – The example of scoring model for one question

In Figure 3 it is shown that the average score of the industrial maturity level for the Croatian manufacturing industry is 2.15, which represent the 2nd industrial generation, i.e. the middle of the 20th century (Veza et al., 2013).

Figure 3 – Level of industrial maturity for specific segment of production and average of entire Croatian industry

Analysis of interviews with CEO’s
The second step was to select the best enterprises and make interviews with their CEOs and technical directors. More than 50 interviews were made in 28 enterprises. The basic elements of the enterprise’s technique, organization and personnel were analysed. The interviewed CEOs and technical directors rated what elements are most important to them using a scale from 0 (irrelevant) to 5 (necessary). In Figure 4 the average rating for each element is presented.

The most important issues, regarding technique, organization and personnel of analysed enterprises, can be summarized as follows (Veza et al., 2013):

- **Technique** – the most relevant issue is the manufacturing equipment, and the most irrelevant are transportation and warehouse equipment. The software, web and network are also very important for enterprises, thus creating a foundation for Computer Integrated Manufacturing (CIM).

- **Organization** – the improvement of the organizational structure is seen as a very important issue. Especially, the introduction of process-oriented or project-oriented organization structure, fractal factory concept or profit centres concept. The main problem is the organization based on the functional organizational structure, which can be found in 74% of all analysed enterprises. Therefore, the
re-organization has been recognised as one of the important issues for Croatian manufacturing enterprises. On the other hand, the introduction of the Toyota Production System, Lean and/or Six Sigma is seen as very important, but they can be found in less than 25% of all analysed enterprises. Networking and work in clusters are seen as the most irrelevant issues.

- Personnel – it is the most important element, for CEOs of analysed enterprises. They see motivation and lifelong learning as more important issues than qualification. So, today, qualification of employees is seen as a mandatory requirement, but it is not a guarantee for success.

![Figure 4 – Evaluation of ratings of technique, organization and personnel and their basic elements](image)

From Figure 4 it is clear that Personnel have been identified as more important issue than Technique and Organization. Furthermore, Lifelong learning and Innovation are seen as most important issues in the development of human resources, i.e. personnel. In order to close the gap between theory and practice, i.e. between what engineering curriculums teach and what manufacturing enterprises do in practice; the Learning Factory has been established on the Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture (FESB) at University of Split.

**Lifelong Learning in Learning Factory at FESB**

Learning Factory at FESB, University of Split is located on 114 square meters large Laboratory for Industrial Engineering (Figure 5). The main aim of Learning Factory at FESB is establishment of “living lab” for research, development, demonstration and knowledge transfer to economy. Tools and methods, included in Croatian model of
Innovative Smart Enterprise (HR-ISE model), adapted to regional fit and modified for laboratory use purposes, will be implemented and presented by demonstration materials, didactic games, working stations with real and didactic products, hardware and software system for Product Lifecycle Management (PLM), etc. “Living lab” will be based on Learning Factory concept, and its development aims will be achieved through support of project Network Innovation Learning Factories (NIL) financed by Deutscher Akademischer Austauschdienst - German Academic Exchange Service (DAAD) and project Innovative Smart Enterprise (INSENT), financed by Croatian Science Foundation (CSF).

In Lean Learning Factory at FESB following activities are in process or finished:
- Education of students;
- Lifelong Learning for people from industry;
- Workshops and summer schools for foreign students and professors;
- Implementation of Lean and Green concept in economy through workshops and seminars;
- Scientific research activities.

For Lifelong Learning activities, a specialized educational platform, developed in EU Leonardo da Vinci project LOPEC, is used (Veza et al., 2014).

LOPEC project as an educational platform for Learning Factory
EU Leonardo da Vinci project called LOPEC (Logistics Personal Excellence by continuous Self-Assessment), had a focus on so-called “grey-collar worker” (Figure 6). The grey-collar worker is an individual that acquires technical or economical skills through professional training or apprenticeship (Jäger et al., 2014). Furthermore, the grey-collar worker requires leadership skills and social competences to promote improvements and changes within his or her work-group. The methodological approach of LOPEC contains of two important aspects that are integrated in one solution. On one side, the self-
assessment in terms of Lean Management and Lean Logistics, and on the other side, the self-assessment for the evaluation of the personal and professional development.

The educational goal system of LOPEC is based on the fundamental mind-set of Lean Management and Operational Excellence [16], with the essential objective on customer focus. LOPEC resulted with e-learning platform with approx. 105 learning modules (Jäger et al., 2014), with the categories and levels which are shown in Figure 7. As supporting subjects, 45 tools got detected as a need for grey-collar workers to be able to apply correlated Lean Management and Lean Logistics tools and methods. To support the learning progress of the learner and to build knowledge in a structured way, a learning path for Excellence in Lean Management with focus on Logistics was designed within LOPEC. This learning path divides the learning modules into 5 maturity levels which represent a performance improvement sequence.

**Figure 6 – Definition of LOPEC target group as end-users**

**Figure 7 – LOPEC content categories and levels**
In terms of Lean Logistics, Level 1 implies the philosophy of Lean Logistics and its principles, with the types of waste material and information flow in particular. Furthermore, analysis tools and optimization tools for the workplace of the grey-collar worker are focus of this Level. Level 2 expands Level 1 with workplace related material movement and handling issues up to the production logistics, the wider working environment of the grey-collar worker. Level 3 concerns analysis tools and optimization methods regarding warehouse management, e.g. container strategies, C-part management or driverless transport systems. Additionally, Level 3 covers the changeover from intralogistics to supply chain management, which is the key aspect of Level 4, which deals with topics such as vendor managed inventory. Level 5 examines tools and methods that do not only affect the production and leadership-specific aspects in logistics sector and theirs correlation to external suppliers, but also organizational, financial and terms of Lean Management.

Furthermore, established logistics knowledge and skills have to be measured. The assessment procedure and the respective measurements covering all criteria must be developed to the appreciation level of a skilled worker to get short-term and long-term benefits towards life-long learning. A model was needed, that scales the achievement avoiding “waste” as essential point of Lean Logistics. Therefrom, the further way of proceeding is based on the PDCA-Circle (Deming, 1986). As a result of the researched maturity models, a self-assessment (“LOPEX”) with six Logistics Maturity Grades (LoMaG), was developed. Grade 0 means that the worker doesn’t know the learning content/method yet. As a result of the adapted PDCA-Circle to Logistics Maturity Grades, the approach refers to “Aware” (Grade 1), “Identified” (Grade 2), “Managed” (Grade 3), “Measured” (Grade 4), “Optimized” (Grade 5).

To demonstrate the operative execution of the presented model, an example of a self-assessment question, using the Lean Logistics topic “clocked route traffic” [19], is given as following (Jäger et al., 2014):

- LoMaG 0 – Unknown: “I am not familiar with this method.”
- LoMaG 1 – Aware: “Clocked route traffic is a method for production logistics.”
- LoMaG 2 – Identified: “I can explain essential reasons for the usage of clocked route traffic.”
- LoMaG 3 – Managed: “I can decide about static and dynamic routes and schedules as well as loading and unloading points.”
- LoMaG 4 – Measured: “I can argue the advantages of clocked route traffic in comparison to single trips in our production.”
- LoMaG 5 – Optimized: “I am involved in the optimization of cycle times, hauls and load trailers used.”

The shop floor worker has to classify his or her knowledge and the ability of application within six grades. After choosing one grade, the assessment tool requires an argumentation or reference to validate the given answer.

Therefore, from e-learning platform to self-assessment, it is clear that LOPEC stands as complete learning platform with potential for easy implementation into Learning Factory, or similar lifelong learning concepts. Although LOPEC is focused on Lean Management emphasizing Lean Logistics, it represents very good educational platform for Learning Factory. Because, if an enterprise has implemented Lean Management, it means it is aware of its processes and it is measuring them. And organization’s knowledge about its processes is a pre-requisition for new concepts like Smart Factory and new platforms like Industry 4.0 (Netland, 2015). Therefore, Lean Management is a first step toward next industrial generation.
Conclusion
In this research, the analysis of the current state of the Croatian manufacturing industry with regard to Industry 4.0 has shown that Croatia is far away from Industry 4.0. An average industrial maturity level of Croatia was estimated to 2.15, which represent the 2nd industrial generation, i.e. the middle of the 20th century. It means that in Croatian manufacturing practice, the technology and organizational concepts are still similar to those 50-60 years ago. The 3rd industrial generation (automated production, production robots, etc.), is not a mainstream in the Croatian manufacturing industry. According to this research, less than 30% of the enterprises belong to Industry 3.0. Additional analysis showed the importance of education of enterprises' personnel, thus emphasizing Lifelong learning. This research is based on establishment of Learning Factory for Lifelong learning and other activities. As Lifelong learning platform, results of EU Leonardo da Vinci project LOPEC (Logistics Personal Excellence by continuous Self-Assessment) have been used. It has been demonstrated that it is clear how, from e-learning platform to self-assessment, LOPEC stands as complete learning platform with potential for easy implementation into Learning Factory, or similar lifelong learning concepts.

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