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SELECTION OF THE BASIC LEAN TOOLS FOR DEVELOPMENT OF CROATIAN MODEL OF INNOVATIVE SMART ENTERPRISE

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Original scientific paper
The research within project Innovative Smart Enterprise (INSENT) was conducted in order to improve scientific understanding of the current state of Croatian manufacturing industry by promoting empirical, enterprise-level research on technological and non-technological processes and organizational innovation. The aim was to understand how manufacturing enterprises in Croatia acquire new manufacturing technologies, ICT integration within processes, new organizational concepts in production such as group work or relocation of production, new products that emerge from process and organizational innovation such as production-related services, and other demands related to Industry 4.0. In order to develop Croatian model of Innovative Smart Enterprise (HR-ISE model), analysis of global and local enterprises, based on literature review and questionnaires, has been made. A selection of six basic Lean tools is made, and foundations of generic configuration of HR-ISE model are defined. In further research, interviews with CEOs of leading Croatian manufacturing enterprises should help creating completely defined HR-ISE model.

Keywords: *Industry 4.0; Lean Management; Toyota Production System*

Izbor osnovnih Lean alata za razvoj Hrvatskog modela Inovativnog pametnog poduzeća

Izvorni znanstveni članak
Cilj istraživanja u sklopu projekta Inovativno pametno poduzeće (INSENT) bio je unaprijediti znanstvenu spoznaju o trenutnom stanju hrvatske prerađivačke industrije kroz empirijska istraživanja, na razini poduzeća, o tehnološkim i ne-tehnološkim procesima i organizacijskoj inovaciji. Cilj je bio razumjeti na koji način prerađivačka poduzeća u Hrvatskoj usvajaju nove proizvodne tehnologije, integriraju IC tehnologiju unutar svojih procesa, usvajaju nove organizacijske koncepte u proizvodnji kao što je rad u skupinama ili relokacija proizvodnje, kako razvijaju nove proizvode proizašle iz procesa i inovativnosti organizacije kao što su proizvodno orijentirane usluge, te ostale zahtjeve Industrije 4.0. U svrhu razvoja hrvatskog modela inovativnog pametnog poduzeća (HR-ISE model), napravljena je analiza globalnih i lokalnih poduzeća utemeljena na istraživanju literature i upitnicima. Napravljen je odabir šest osnovnih alata, te su postavljeni temelji generičke konfiguracije HR-ISE modela. U daljnjem istraživanju, intervjui s menadžerima vodećih hrvatskih proizvodnih poduzeća pomoći će bolje definirati HR-ISE model.

Ključne riječi: *Industrija 4.0; Lean menadžment; Toyota proizvodni sustav*

1 Introduction

The process of globalization, liberalization of international trade and the global economic crisis in 2007 showed that classical vision of the enterprise and its business activities cannot survive in today's turbulent economy. Globalization has created new enormous challenges for today's enterprises: fierce competition, short windows of market opportunity, frequent product introductions and rapid changes in product demand. Many manufacturing enterprises have moved away from a mass production orientation to more agile production approaches. The challenge is to succeed in a turbulent business environment where all competitors have similar opportunities, and where customer wants personalized product [1].

1.1 Smart Enterprise

The first three industrial revolutions came about as a result of mechanization, electricity and IT. Now, the introduction of the Internet of Things and Services into the manufacturing environment is leading towards the fourth industrial revolution: Industry 4.0 [2]:

- *1st Industrial revolution* – introduction of water-powered and steam-powered mechanical manufacturing facilities.
- *2nd Industrial revolution* – introduction of electrically-powered mass production based on the division of labor.
- *3rd Industrial revolution* – introduction of electronics and IT to achieve automation of manufacturing.
- *4th Industrial revolution* – introduction of Internet of Things and Cyber-Physical Systems into the manufacturing environment.

This new type of industry is based on Smart Factory model. The embedded manufacturing systems are vertically networked with business processes within enterprises and horizontally connected to the dispersed value networks that can be managed in real time. Smart Factories allow individual customer requirements to be met and mean that even one-off items can be manufactured profitably. In Industry 4.0, dynamic services and engineering processes enable last-minute changes to production and generate the ability to respond more flexibly to disruptions and failures on behalf of suppliers.

Hence, the main features of Smart Enterprise can be summarized into the following:

- *Smart personalized product* – Requires flexibility and high level of ICT integration into manufacturing system to produce a product which fits the customer's exact needs and which is uniquely identifiable, may be located at all times and knows its own history, current status and alternative routes to achieving customer. It can be realized through Reconfigurable Manufacturing System [3] or Industry 4.0 Smart Factory [2].
- *Product and service provider* – Ability to offer extended products: product and service integrated

into single product for delivering value in use to the customer during the whole life cycle of a product; or to offer manufacturing as a service and become manufacturing service provider [4]. It can be realized through specialized Internet portals and Cloud computing [5].

- *High level of collaboration* – Also requires high level of ICT integration to support collaborative product development, collaborative manufacturing and all other value adding processes [6]. It can be achieved through vertical integration called Production Networks [7], or through horizontal integration called Manufacturing Networks.

Every global manufacturer has its unique manufacturing system (Toyota, Daimler, Bosch, etc.), and some countries are developing their own unique enterprise model (like Germany – Industry 4.0). Model is aligned with their vision, strategy, values and culture. Croatia has not developed its own model of enterprise yet. Model developed in this project should be original and unique for Croatian enterprises. Therefore, it could be implemented in the economy, particularly in small and medium-sized enterprises.

1.2 Application of Lean tools in Croatian manufacturing industry

Since focus of this research was Croatian manufacturing industry, it is important to give a brief overview of researches about application of Lean tools. Researchers like Cajner et al. [8] and Stefanic et al. [9, 10] have made general research on application of Lean management in Croatian industrial enterprises. Other researches put focus on different type of industries like: beverage industry (Veza et al. [11]), automotive industry (Pipunic and Grubisic [12]), telecommunication industry (BosiljVuksic and Ivancan [13]), etc.

General conclusion is that Lean management philosophy is not implemented in Croatian industrial enterprises, but some Lean tools are used. For instance, in automotive industry most of the enterprises are using 2-3 Lean tools [12], and those with higher number of customers have tendency to use higher number of Lean tools like 5 or more [12]. Enterprise dealing with production of power lines is trying to improve its production process using Value Stream Mapping [10]. Many enterprises use Kaizen to decrease change-over times [9], which are non-value adding activities, and 5S for workplace management [11]. Furthermore, it is suggested by Cajner et al. [8] that Croatian enterprises are lacking in measurement of Lean management indicators. In telecommunication industry Lean is even extended with Six Sigma methodology [13].

From the literature overview, it is clear that some Lean tools, like Kaizen, Value Stream Mapping, 5S – Workplace management, are used in Croatian manufacturing tools. Therefore, this research has put focus on application of Lean tools in order to select basic Lean tools that every enterprise should implement. It is mandatory if enterprise wants to move toward Industry 4.0. Because, without Lean, it is most-likely that enterprise is lacking knowledge about its processes and their key indicators.

1.3 Development of Lean framework for Production Systems

Many researches about Lean management have tendency to develop some Lean model or framework that could be implemented in many enterprises. Generally, some researchers are focused on development of Lean framework for whole enterprise (Cookand Graser [14], Karlssonand Ahlstrom [15]) and some are focused on development of Lean framework for manufacturing system only (Höökand Stehn [16], James-Mooreand Gibbons [17], Sanchez and Perez [18]).

Eventually, all these Lean frameworks are some kind of organizational model based on Lean tools. Usually, they are visualized as house with pillars [19, 20], like the original Toyota Production System [21]. In this research, the same idea is proposed and selection of basic lean tools for development of Croatian model of Innovative Smart Enterprise is made.

2 Project Innovative Smart Enterprise (INSENT)

Last year's developments are a turning point for the whole European industry, characterized by dramatic drop in customer demand leading to working hours decrease, layoffs and idle factories. As a consequence, in the future the overriding objectives in Croatian enterprise should be: flexibility, agility and scalability, in order to survive shocks caused by global market turbulences.

The main objective of this project is to develop Croatian model of Innovative Smart Enterprise (HR-ISE model). The aim is to perform the model's regional fit, i.e. to harmonize Innovative Smart Enterprise model with specific regional way of thinking, manufacturing and organizational tradition, specific education, and especially to help Croatian enterprises in reducing the gap between their competencies and EU enterprises' competencies and capabilities.

The following objectives are crucial to achieve main objective of this project:

- *Objective 1:* It is important to perform profound research to describe current state of 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, analysis will be done to describe current state of Croatian manufacturing enterprise. It will be the answer to the question: "Where are we?"
- *Objective 2:* A synthesis of analysis of Croatian manufacturing enterprises through development of Croatian model of Innovative Smart Enterprise (HR-ISE model), will be done. HR-ISE model will be based not just on State-of-the-art theoretical models but also on State-of-the-art practical models like Lean Management philosophy. 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 to 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 (virtual reality gadgets, specialized assembly tables, etc.). Laboratory will be organized 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 the transfer of developed HR-ISE model to the economy subjects will be achieved. It will be the answer to the question: "How can we get there?"

2.1 Analysis of the current state of Croatian manufacturing industry with regard to Industry 4.0

Project INSENT tends to improve the scientific understanding of Croatian manufacturing enterprise by promoting empirical, enterprise-level research on technological and non-technological process and organizational innovation. Technological and non-technological process and organizational innovation includes the introduction of new production technologies, level of ICT integration with processes, new organizational concepts in production, but also in new products that emerge from process and organizational innovation, such as product-related services. After the data have been gathered, a profound analysis will be made in order to describe current state of Croatian manufacturing enterprise.

Table 1 Structure of sample based on enterprise size

Enterprise size	No. of enterprises	%
Micro enterprise (5 ÷ 9 employees)	23	14,3
Small enterprise (10 ÷ 49 employees)	63	39,1
Medium enterprise (50 ÷ 249 employees)	48	29,8
Large enterprise (more than 250 employees)	27	16,8

The questionnaire has been sent to more than 1980 industrial enterprises. Database "Biznet.hr" of Croatian Chamber of Economy was used. A sample of 8 % of total, representing 161 enterprises, has been gathered. By taking the geographical coverage (Fig. 1) and the coverage of enterprises size (Tab. 1) into account, a sample should be considered as the representative one.

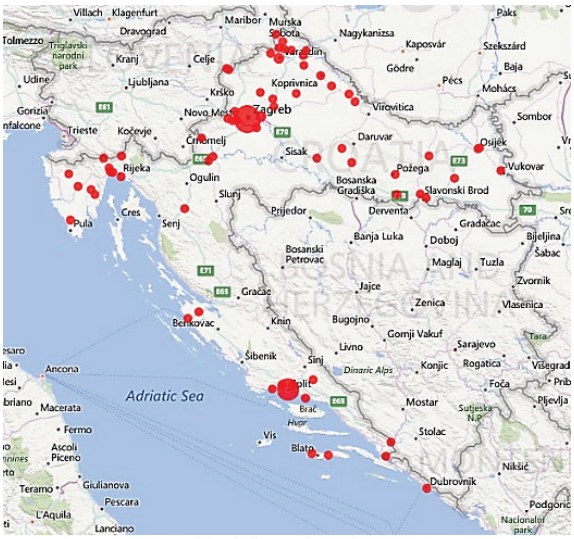

Figure 1 Geographical dispersion of sample (enterprises)

Beside basic questions about enterprise itself, a set of nine questions that represent most important aspects of manufacturing, was given as follows:

1) Product development,
2) Technology,
3) Work orders management in your production system,
4) Monitoring of production traceability,
5) Materials inventory management,
6) Finished products stocks management,
7) Quality Assurance,
8) Product Lifecycle Management,
9) Application of Toyota Production System TPS and Green and Lean Production GALP concept.

Each answer was converted to a score from 1 to 4 representing one of the four historical industrial generations. 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 third industrial generation and its score is 3.0. Using that approach, an average score has been calculated for each of nine aspects of manufacturing. Finally, overall average represents industrial maturity level of Croatian manufacturing industry (Fig. 2). Distribution of enterprises according to their industrial maturity level is presented in Fig. 3.

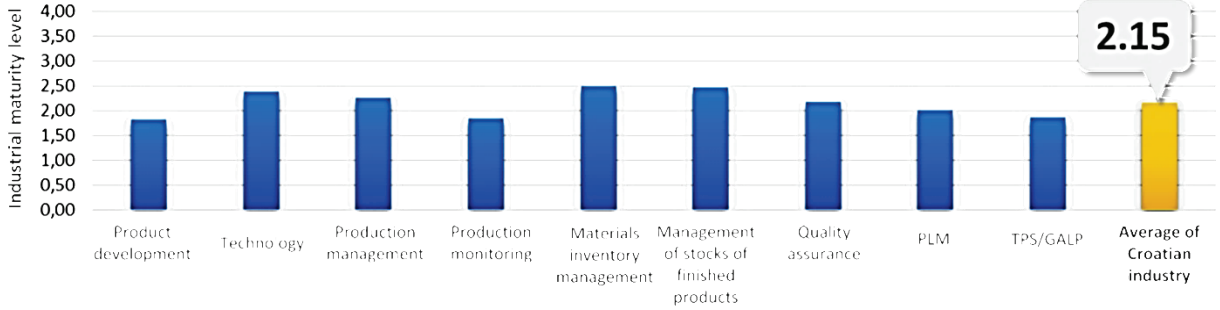

Figure 2 Average level of industrial maturity for specific segment of production and the average of all segments for entire Croatian industry

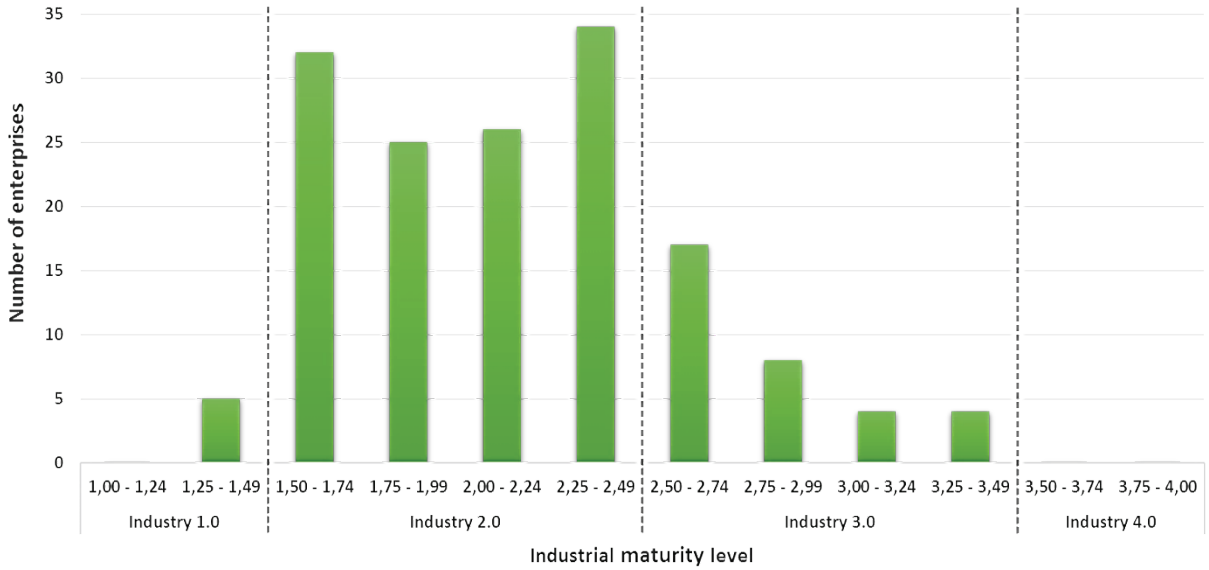

Figure 3 Distribution of enterprises from Croatian industry according to their industrial maturity level

In Fig. 2, it is shown that average score of industrial maturity level for Croatian manufacturing industry is 2.15 which represents 2nd industrial generation, i.e. middle of 20th century. Since most of the enterprises have a score between 1.50 and 2.49 (Fig. 3), they belong to 2nd industrial generation. Some of enterprises belong to 3rd industrial generation, and none of the enterprises is in 4th industrial generation, i.e. Industry 4.0. So, current state of Croatian manufacturing industry is not Industry 4.0, but Industry 2.15.

2.2 Application of Lean and Green in Croatian manufacturing industry

For further development of Croatian manufacturing industry two hypotheses must be taken into account:

1) Implementation of Lean is the foundation for all other activities that are to be undertaken in order to increase competitiveness of the enterprise;
2) The enterprise which did not finish its "homework" on the theme of Lean cannot progress toward Industry 4.0.

The important and mandatory transformation procedure can be described with two main activities:

1) Implement Lean principles into most important business/technological processes and support them with intelligent automatization;
2) Connect personnel and technology in order to achieve better competitiveness.

Therefore, in this research a special focus has been put on Lean (question no. 9 in above described analysis): "Select an answer that describes best the application of Toyota Production System TPS and Green and Lean Production GALP concept in your production system". The answers to this question are presented in Tab. 2.

Table 2 Answers to question about TPS and GALP principles

No.	Question	No. of enterprises	%
1	Do not use either TPS or GALP principles	120	74,5
2	Use some elements of TPS and GALP	37	23
3	TPS and GALP principles are introduced through the entire business process (Lean Management 2.0)	4	2,5

From Tab. 2 it is clear that 75 % of enterprises do not use any TPS or GALP principle. So, it represents the main obstacle in the journey of Croatian manufacturing toward Industry 4.0. Therefore, in this research additional analysis is made to find out what are the basic Lean tools that Croatian enterprises should acquire and use.

3 The analysis of application of Lean tools in Croatian enterprises in relation with global enterprises

Following step was to make an analysis of application of Lean tools, similar to Netland [20]. Tab. 3 presents the reference framework. It summarizes 34 principles from Ohno's "Toyota Production System" [21], Womack and Jones' "Lean Thinking" [22], Shah and Ward's "Lean manufacturing: Context, bundles, and performance" [23], Liker's "The Toyota Way" [24], and extended with principles that Kovacec collected in his Ph.D. Thesis [25] at the University of Zagreb, Croatia.

3.1 The analysis of application of Lean tools in Croatian enterprises

Kovacec in his Ph.D. thesis [25] searched for model for efficient management of production systems of Croatian enterprises. Therefore, he interviewed top managers from 176 Croatian enterprises. The structure of enterprise size based sample is presented in Tab. 4.

Table 3 Reference framework for Green and Lean principles based on key TPS and lean literature

TPS /Lean principle	Ohno [21]	Womack & Jones [22]	Shah & Warg [23]	Liker [24]	Kovacec [25]
Jidoka / automation	X			X	X
Value stream	X	X		X	X
Performance measurement	X		X		
Flow orientation	X	X	X		X
Continuous improvement / Kaizen	X	X	X	X	X
Just-in-time (JIT)	X		X	X	X
Total quality	X		X	X	
Leadership / Genchigenbutsu	X			X	
Cross functional training	X		X	X	
Employee involvement	X			X	
Teamwork	X		X	X	
Flexibility	X				
Heijunka / Levelled production	X		X	X	
Profit-making industrial engineering	X				
New and effective technology	X		X		
Visualisation	X			X	
Communication	X				
Quick change-over SMED	X		X	X	X
Reduction of batch size	X		X		
Standardised work	X			X	X
Inventory management	X				
Takt time	X			X	X
Maintenance (TPM)	X		X		X
Pull system		X	X	X	X
Customer focus		X			
Competitive benchmarking			X		
Focused factory production			X		
Order and material planning			X		
Health, Safety and Environment (HSE)			X		
Lean supply chain				X	
Stability and robustness				X	
Vision, culture and values				X	
Workplace management					X
Poka Yoke					X

Table 4 Structure of sample based on enterprise size

Enterprise size	No. of enterprises	%
Micro enterprise (5 ÷ 9 employees)	62	35,2
Small enterprise (10 ÷ 49 employees)	48	27,3
Medium enterprise (50 ÷ 249 employees)	43	24,4
Large enterprise (more than 250 employees)	23	13,1

Kovacec's analysis ranked Green and Lean tools and 12 also selected tools as the most important ones (Tab. 5). However, his analysis is lacking in the aspect of personnel, for example employee involvement, team work, leadership and quality (total quality management).

In his analysis, Kovacec used three steps of Analytic Hierarchy Process (AHP) to rank Green and Lean tools, as presented in Tab. 5. Analysis showed that the most important tool for Croatian enterprises is Just-In-Time principle, followed by Kaizen, Flow orientation, Standardized work etc. It is important to have in mind that the majority of Croatian manufacturing enterprises are in lower part of supply chain, i.e. they are original equipment manufacturers, instead of final product producers. That is why Just-in-Time principle is most important to them, because they are usually conditioned by enterprises from top of the supply chain to deliver just-in-time.

Table 5 Rank of importance of Green and Lean tools according to analysis of 176 Croatian production systems

Rank	Principle	Importance %
1	Just-in-Time	12,07
2	Continuous improvement – Kaizen	11,17
3	Flow orientation	10,26
4	Standardized work	10,23
5	Value Stream Mapping	9,68
6	Maintenance (TPM)	9,11
7	Pull system	7,28
8	Workplace management	7,27
9	Jidoka	6,28
10	Poka Yoke	5,81
11	Takt time	5,50
12	Quick change-over SMED	5,34

3.2 The analysis of application of Lean tools in global enterprises

The XPS or Any-Production System can be described as the improvement programme or continuous improvement Management System for the production system. Tab. 6 sums up the frequency and percentage of principles in the 30 analysed XPSs of 30 global (multinational) enterprises, made by Netland [20]. The bulk of XPS principles fit right into the reference framework (Tab. 3). However, the reference principles

did not cover 14 "new" principles, with only five among them that had more than two occurrences (asterisks indicate the new principles).

Table 6 Rank of occurrence of Green and Lean tools according to analysis of 30 global production systems (XPSs) [20]

Rank	Principle	No. of XPSs	% of XPSs
1	Standardised work	28	93
2	CI / Kaizen	25	83
3	Total quality	23	77
4	Pull system	21	70
5	Flow orientation	20	67
6	Value stream	20	67
7	Employee involvement	19	63
8	Visualisation	18	60
9	Customer focus	17	57
10	Stability and robustness	15	50
11	Workplace management*	15	50
12	Just-in-Time	14	47

The main conclusion of the XPSs content comparative analysis from the 30 multinational enterprises was that "XPSs represent an own-best-way approach to the one-best-way paradigm" [20]. This means two things. First, multinational enterprises largely choose the same principles (the one-best-way); and second - the systems, however, contain enterprise-specific elements (the own-best-way) which makes the XPS more tailored to the enterprise than generic improvement philosophies [20].

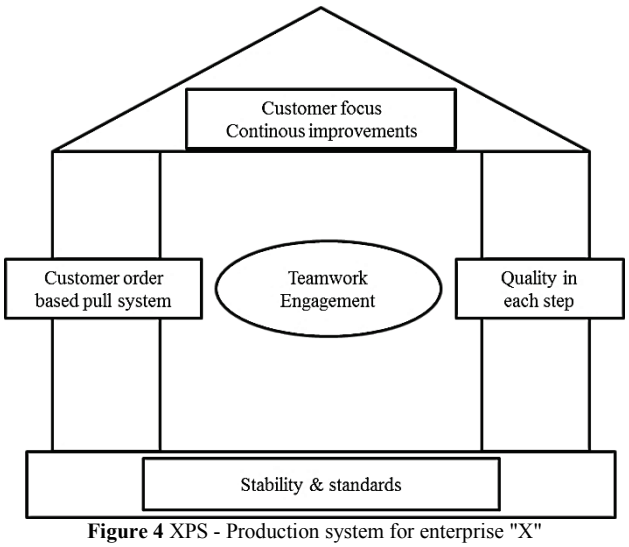

Figure 4 XPS - Production system for enterprise "X"

4 Results and discussion

4.1 Relating the XPS to the TPS and Green and Lean principles

According to Netland [20], XPS principles largely resemble the principles of the TPS and Green and Lean. It becomes clear from the comparison that the overall resemblance of principles from the TPS and Lean production paradigm should be considered high.

The top-ten principles are represented in 50 ÷ 93 % of the XPSs. Lean principles either highly influence or actually form the basis of the majority of the XPSs. This, however, does not represent a radical finding, because most enterprises explicitly state that TPS and lean thinking heavily influenced their XPS development [20].

However, if generic model is to be made, like "TPS house" model, few main principles should be identified. According to Netland's research "generic house" XPS model for enterprise "X" should look like the one presented in Fig. 4.

4.2 Selection of basic Lean tools for HR-ISE model

The main aim of this research was to establish certain phases and steps for process and structural reorganization of average Croatian enterprise based on Green and Lean principles. It is a kind of Green and Lean concept's regional fit. It represents foundation for development of Croatian model of Innovative Smart Enterprise: HR-ISE model. Thus, HR-ISE model should be aligned with regional vision, strategy values and culture. However, first step is to select basic Lean tools that should be acquired and implemented.

Synthesis of Green application analysis and Lean tools in Croatian enterprises [25] and application of Lean tools in 30 global (multinational) enterprises [20] is the cognition that there are six most important Lean tools that any Croatian enterprise should acquire and implement. These tools, ranked according to research in Croatia, are:

1) Just-in-Time
2) Continuous improvement – Kaizen
3) Flow orientation
4) Standardized work
5) Value Stream Management
6) Pull system.

These six Lean tools represent basic tools for HR-ISE model of production system. Therefore, they represent irreplaceable part of HR-ISE house model (Fig. 5).

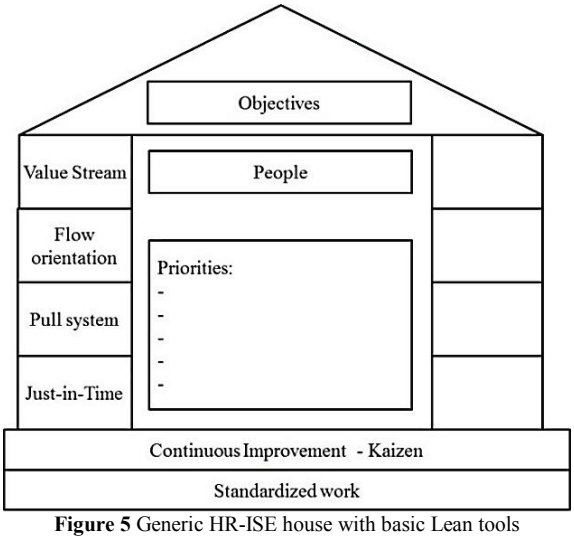

Figure 5 Generic HR-ISE house with basic Lean tools

Other elements (tools and principles) will be defined after interviews with CEOs of leading Croatian manufacturing enterprises, but they can also be enterprise-specific. This further analysis will complete the HR-ISE house model:

- The Roof – Objectives (e.g. Higher market share, Higher quality, Lower costs...)

- Personnel (e.g. Human potential conviction, Collaboration, Trust, Communication, Relationship focus…)
- Priorities (e.g. Safety, Environment, Quality, Delivery, Cost, Teamwork, Customer…).

The comparison of the selected Lean tools importance, for Croatian and global enterprises is presented in Fig. 6. Note that for global enterprises, occurrence of some tool was converted into importance score.

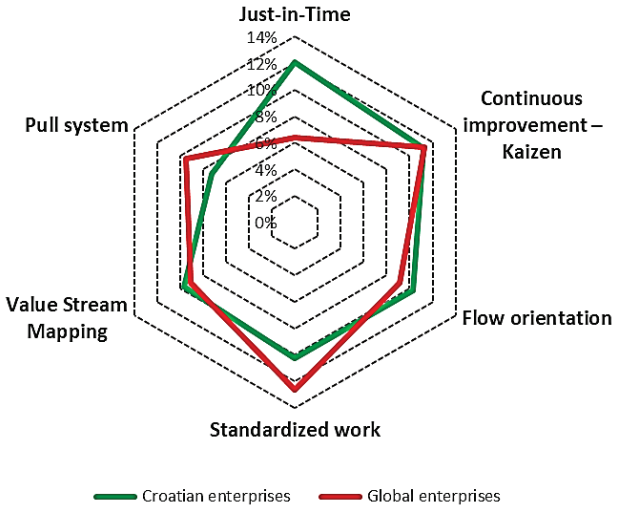

Figure 6 Comparison of importance, of selected Lean tools, for Croatian and global enterprises

In Fig. 6, the only significant difference is importance of Just-in-Time principle, which is twice more important to Croatian enterprises than global enterprises. It is because of the reason (already mentioned above), that Croatian manufacturing enterprises are in the lower part of supply chain, i.e. they are original equipment manufacturers, instead of final product producers. That is why Just-in-Time principle is very important to them.

5 Conclusion

In this research, the analysis of the current state of Croatian manufacturing industry, with regard to Industry 4.0, was made. It has shown that Croatia is far away from Industry 4.0. An average industrial maturity level of Croatia was estimated to be at 2.15 which represent the 2nd industrial generation, i.e. middle of the 20th century. The 3rd industrial generation (automatized production, production robots, etc.), is not the mainstream in Croatian manufacturing industry. Less than 30 % of enterprises belong to Industry 3.0 according to this research. Furthermore, analysis showed that 75 % of enterprises do not use any Toyota Production System or Green and Lean principle. That fact represents the main obstacle in the journey of Croatian manufacturing toward Industry 4.0. The enterprise which did not finish its "homework" on the theme of Lean cannot move toward Industry 4.0.

Therefore, in this research additional analysis was made to find out what are the basic Lean tools that Croatian enterprises should acquire and use. A selection of six basic Lean tools is made, and foundations of generic configuration of Croatian model of Innovative Smart Enterprise (HR-ISE) model are defined. In further research, interviews with CEOs of the leading Croatian manufacturing enterprises will help in creating a completely defined HR-ISE model.

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