Evaluation of Industrial Maturity Level: A Case Study of Croatia

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ABSTRACT

The first three industrial revolutions came about as a result of mechanization, electricity and IT. Therefore, the introduction of the Internet of Things and Services into the manufacturing environment is starting a fourth industrial revolution: Industry 4.0. This new type of industry is based on the Smart Factory model. 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 business and engineering processes enable last-minute changes to production and deliver the ability to respond flexibly. However, the question is how much of this is close to the reality, or, on the other hand, how far away are enterprises from this new industrial platform? The Project Innovative Smart Enterprise wants to improve the scientific understanding of an average Croatian manufacturing enterprise, by promoting empirical, enterprise-level research on technological and non-technological process and organizational innovation. It will help develop a regional model of innovative smart enterprise based, not just on the State-of-the-art theoretical models, but also on the State-of-the-art practical models like the Lean Management philosophy from the Toyota Production System. Special efforts will be made to bridge the cultural and mentality gap between Croatian and EU manufacturing enterprises. In order to enable the development of the Croatian model of Innovative Smart Enterprise, it was mandatory to analyse the current state of the Croatian manufacturing industry. For the evaluation of the industrial maturity level a questionnaire covering nine different aspects was designed (for instance: design, technology, manufacturing, quality assurance, etc). The research was made using Web questionnaires and interviews with CEOs and/or technical directors of manufacturing enterprises. The analysis to describe the current state of the Croatian manufacturing enterprise was based on the responses of 161 enterprises and interviews with 28 CEO from Croatia. A synthesis of this research has been made and some suggestions for finding a path toward Industry 4.0 are given.

1. INTRODUCTION

The process of globalization, liberalization of international trade and the global economic crisis in 2007 showed that the classical vision of the enterprise and its business activities cannot survive in today's turbulent economy. Globalization has created a 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]. Furthermore, 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 ushering in a 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 labour.
- *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 the 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

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mean that even one-off items can be manufactured profitably. In Industry 4.0, dynamic business and engineering processes enable last-minute changes to production and deliver the ability to respond flexibly to disruptions and failures on behalf of suppliers, for example. 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 realized through vertical integration called Production Networks [7], or through horizontal integration called Manufacturing Networks [8].

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

2. OBJECTIVES OF PROJECT INSENT

Last year's developments are a turning point for the whole European industry, characterized by a dramatic drop in customer demand leading to reduced working hours, layoffs and idle factories. As a consequence, in the future the overriding objectives in the Croatian enterprise will be flexibility, agility and scalability, in order to survive turbulences caused by erratic customer behaviour on the one hand, and market turbulences on a large scale on the other hand.

Therefore, the project Innovative Smart Enterprise (INSENT) was started to increase competitiveness of Croatian industrial enterprises. The main objective of this project is to develop the Croatian model of Innovative Smart Enterprise (HR-ISE model). The aim is to perform the model's regional fit, i.e. to harmonize the Innovative Smart Enterprise model with a specific regional way of thinking, manufacturing and organizational tradition, specific education, and especially to help Croatian enterprises to bridge the gap between their competencies and EU enterprises' competencies and capabilities. The following objectives are crucial to achieve the 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 the development of the Croatian model of Innovative Smart Enterprise (HR-ISE model). The HR-ISE model will be based not just on the State-of-the-art theoretical models but also on the State-of-the-art practical models like the Lean Management philosophy from the Toyota Production System. Special efforts will be made to bridge the cultural and mentality gaps between the State-of-the-art models and the 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. a simulation of a real factory through specialized equipment (virtual reality gadgets, specialized assembly tables, real products, automatic assembly station, etc.). The laboratory will be organized to simulate a factory based on the HR-ISE model. Hence, the Laboratory will be the learning environment not only for the students but also for the engineers from manufacturing enterprises. It will be a place in which the transfer

of the developed HR-ISE model to the economy subjects will be achieved. All supporting materials and equipment for education will be provided. It will be the answer to the question: "How can we get there?"

At the moment, Objective 1 of the project INSENT was achieved and its results are partially presented in this paper. Furthermore, some of the results of Objective 2, which is planned to be achieved in the next year, are also presented.

3. ANALYSIS OF CURRENT STATE OF CROATIAN MANUFACTURING ENTERPRISE

The Project INSENT wants to improve the scientific understanding of the Croatian manufacturing enterprise by promoting the empirical, enterprise-level research on the 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, but 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. The literature review was a foundation for the design of questionnaires for Web and for visits (Figure 1).

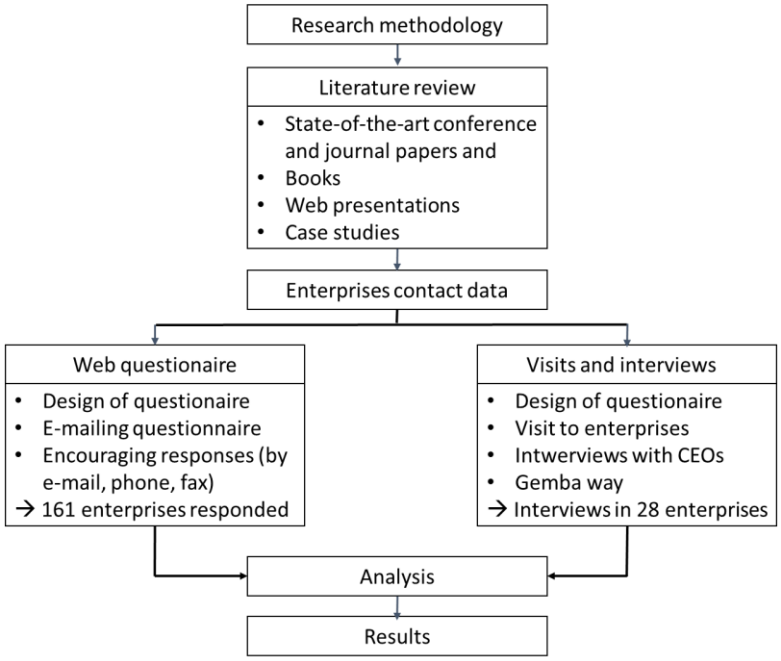

Figure 1: Methodology for obtaining maturity level of Croatian industrial enterprises

3.1. ANALYSIS OF WEB QUESTIONNAIRE RESPONSES

The 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 (Figure 2) and industrial sectors coverage (Figure 3), the sample can be considered as a representative one.

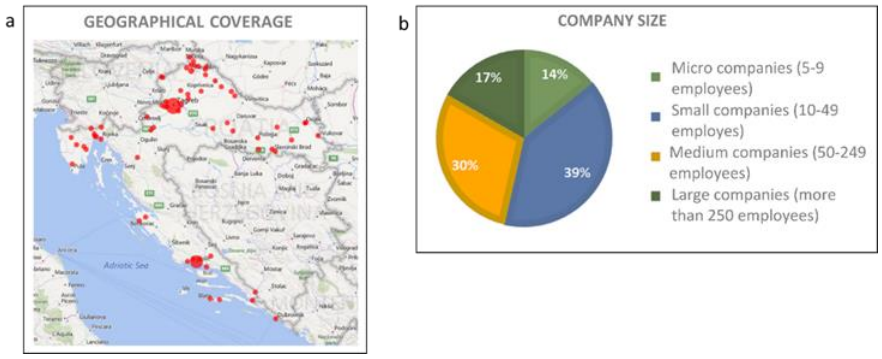

Figure 2: (a) Geographical coverage of sample; (b) Structure of sample based on enterprise size

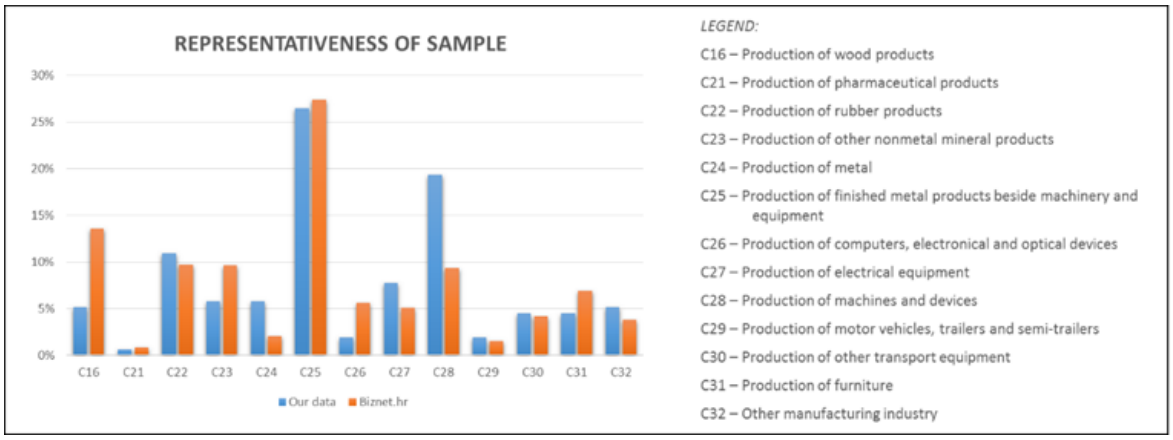

Figure 3: Structure of sample based on industrial sector

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. 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 4).

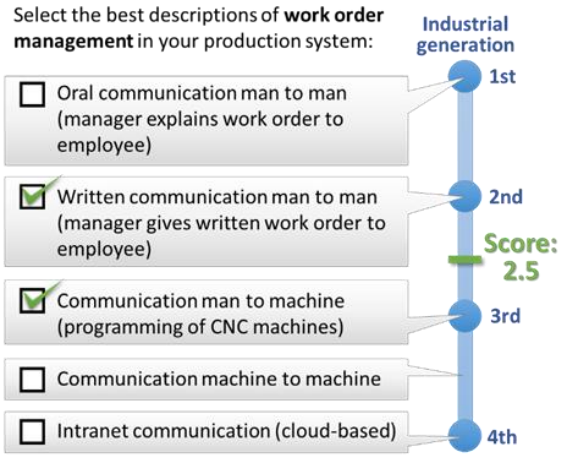

Figure 4: The example of scoring model for one question

In the following figures (Figure 5 and 6), overall results of the questionnaire, such as the industrial maturity level of the Croatian manufacturing industry, are presented. In Figure 5 it is shown that the average score of the industrial maturity level for the Croatian manufacturing industry is 2.15 which represents the 2nd industrial generation, i.e. the middle of the 20th century. In Figure 6, it can be seen that most of the enterprises have values between 1.50 and 2.49, and belong to the 2nd industrial generation. Some of the enterprises belong to the 3rd industrial generation, and none of the enterprises are in the 4th industrial generation, i.e. Industry 4.0. So, the current state of the Croatian manufacturing industry is not Industry 4.0, but Industry 2.15.

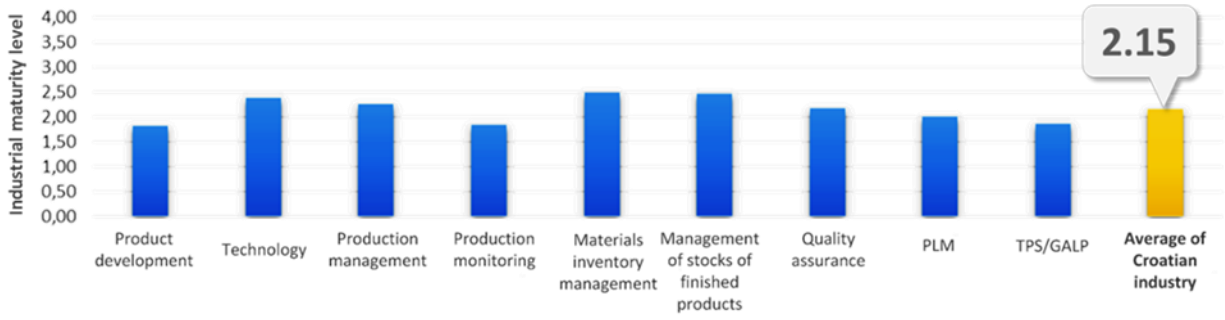

Figure 5: Level of industrial maturity for specific segment of production and average of entire Croatian industry

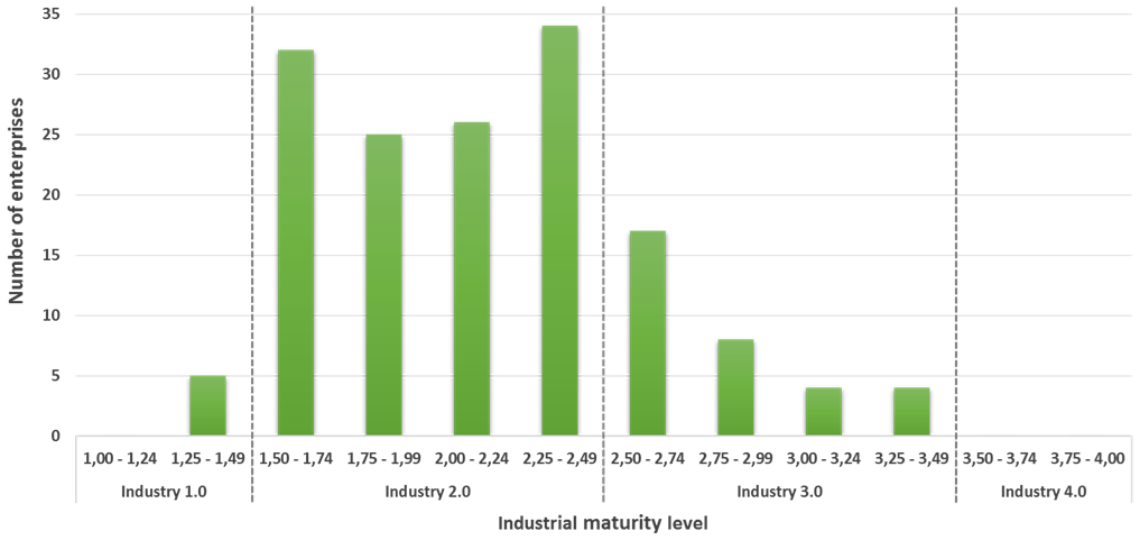

Figure 6: Positioning enterprises according to their industrial maturity

3.2. ANALYSIS OF INTERVIEWS WITH CEOS

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 7 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:

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

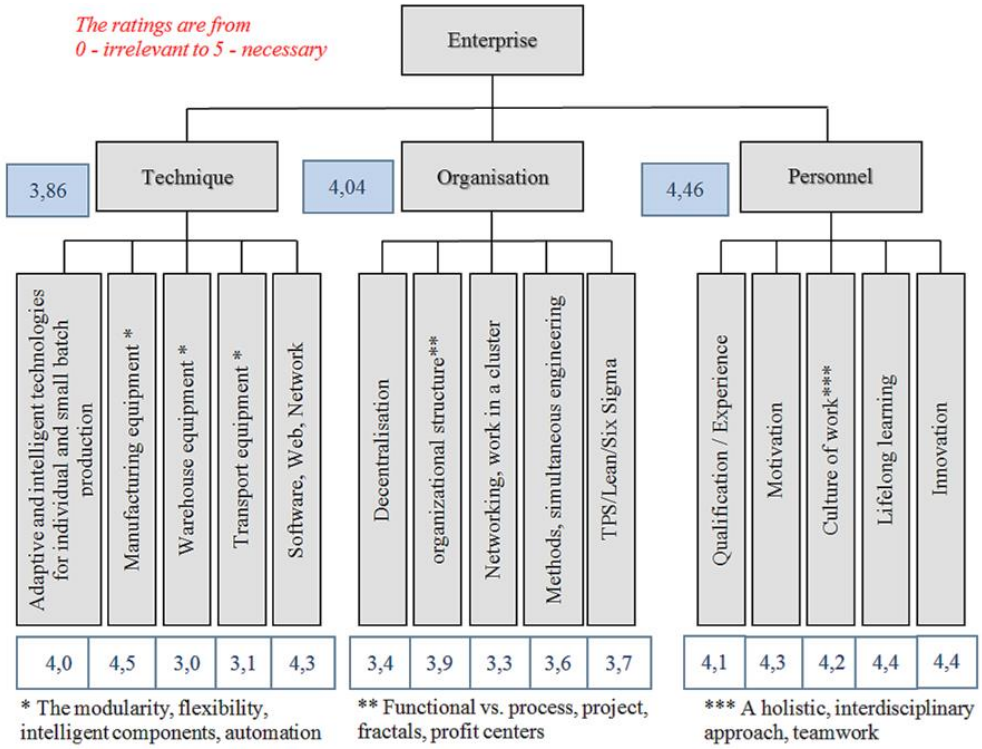

Figure 7: Evaluation of ratings of technique, organization and personnel and their basic elements

The next step was to use both analysis (Web questionnaire and Interviews) to calculate the maturity level for the enterprise's technique, organization and personnel separately. The scale has been set from 1 to 4, which represents four industrial generations. This approach creates the Technique-Organization-Personnel space in which 28 analysed enterprises are positioned. Figure 8 shows the results of this analysis.

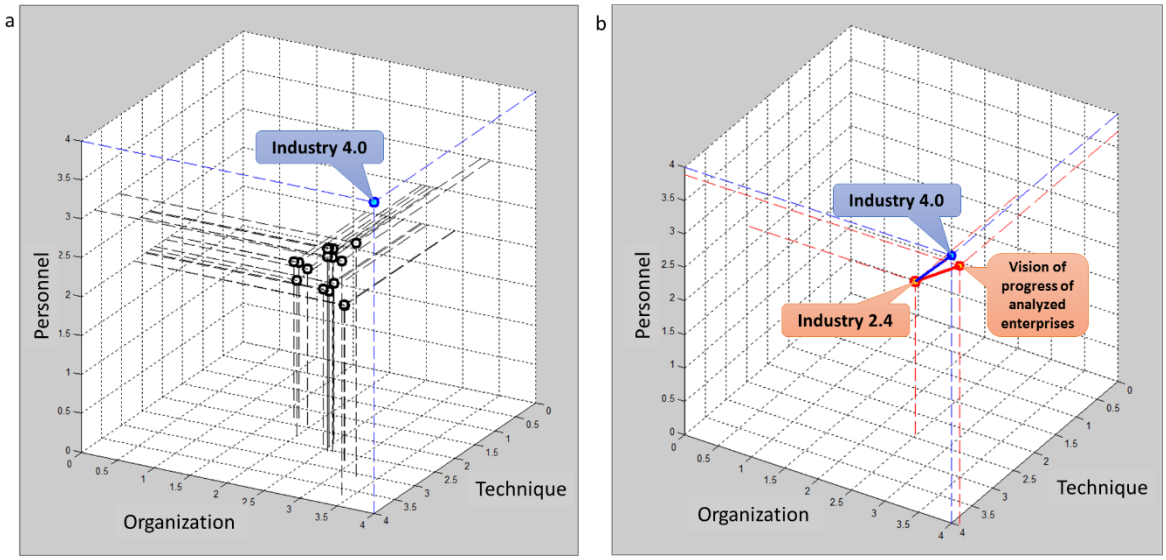

Figure 8: (a) Position of some analysed enterprises in Technique-Organization-Personnel space; (b) Comparison of vision of progress of analysed enterprises regarding Industry 4.0

In Figure 8a, the positions of some analysed enterprises in the Technique-Organization-Personnel space are presented, and after that the mean position has been calculated, which is presented in Figure 8b. The average value of

the industrial maturity level of 28 analysed enterprises is 2.4, which represents the 2nd industrial generation. From the evaluation of the technique ratings, the organization and personnel (Figure 7), relative values have been calculated (Table 1) as a relative importance of investment in a particular element. These three relative values create the progress vector in the Technique-Organization-Personnel. That progress vector has been compared with the progress vector needed to achieve the Industry 4.0 level. This comparison is presented visually in Figure 8b and arithmetically in Table 1. It shows that the enterprises need to invest in personnel more than they plan and less in organization. It is interesting that enterprises have a clear vision how much they need to invest in technique, i.e. exactly 31.2%.

Table 1: Comparison of vision of progress of analysed enterprises and progress needed to achieve Industry 4.0 level

	Relative importance of investments in technique	**Relative importance of investments in organization**	**Relative importance of investments in personnel**
Vision of progress of analysed enterprises	31.2 %	32.7 %	36.1 %
Progress needed to achieve Industry 4.0 level	31.2 %	28.5 % ↓	39.8 % ↑

4. CONCLUSION

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 represents the 2nd industrial generation, i.e. the middle of the 20th century. It means that in the Croatian manufacturing practice the technology and organizational concepts are still similar to those 50-60 years ago. The 3rd industrial generation (automatized production, production robots, etc.) is not mainstream in the Croatian manufacturing industry. Less than 30% of the enterprises belong to Industry 3.0 according to this research. An additional analysis of the technique, organization and personnel showed that enterprises do not have a clear vision of their progress toward Industry 4.0. Accordingly, they should invest more in the personnel than in the organization and the technique. It is interesting that CEOs see their personnel as the most important element of their enterprise, but this analysis showed that it should be even more important. The personnel seek for investments in lifelong learning and motivation through financial bonuses, and similar. All these findings will be acquired in the development of the Croatian model of Innovative Smart Enterprise (HR-ISE model).

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