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ASSESSMENT OF INDUSTRIAL MATURITY LEVEL BY MULTI-CRITERIAL ANALYSIS*

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Abstract: *Project Innovative Smart Enterprise wants to improve the scientific understanding of average Croatian manufacturing enterprise, by promoting empirical, enterprise-level research on technological and non-technological process and organizational innovation. A special effort will be made to bridge the cultural and mentality gap between Croatian and EU manufacturing enterprises. In order to enable development of Croatian model of Innovative Smart Enterprise, it was mandatory to analyse current state of Croatian manufacturing industry. Evaluation of industrial maturity level research is carried out using Web questionnaires and interviews with 50 CEOs (chief executive officer) from 38 manufacturing enterprises. The problem of industrial enterprises evaluation is solved by a model that combines Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).*

Key Words: *Manufacturing enterprises, Industry 4.0, AHP, TOPSIS.*

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 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]. 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 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.

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 hasn't developed its own model of enterprise. Model developed in this project would be original and unique model for Croatian enterprises and it could be implemented in economy, especially in small and medium-sized enterprises.

2. ANALYSIS OF CURRENT STATE OF CROATIAN MANUFACTURING ENTERPRISE

Project INSENT wants 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 such as group work or relocation of production, but also in new products that emerge from process and organizational innovation, such as product-related services.

In order to obtain maturity level of Croatian industrial enterprises a specialized methodology has been established. It consisted of profound literature review, questionnaires and visits with interviews. The literature review was foundation for design of questionnaires for Web and for visits (Figure 1).

*Note: This Paper has been published in Total Quality Management Proceedings, 2017

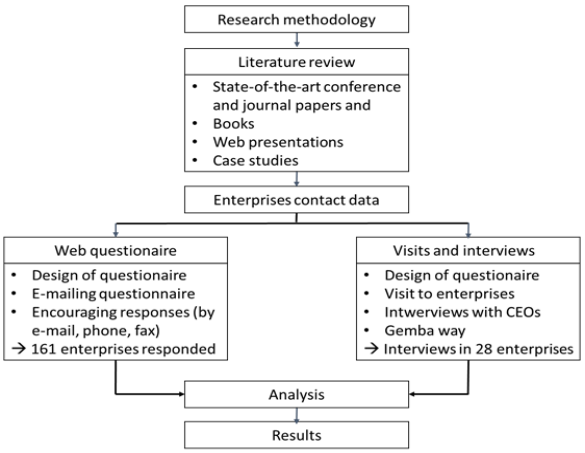

Figure 1. Methodology for obtaining maturity level of Croatian industrial enterprises

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. A sample of 8% of total, representing 161 enterprises, has been gathered.

Beside basic questions about enterprise itself, a set of nine questions, representing most important aspects of manufacturing, was made:

1. Select the best description of product development phase in your enterprise
2. Select the best description of technology in your production system
3. Select the best description of work orders management in your production system.
4. Select the best description of monitoring production traceability in your production system
5. Select the best description of materials inventory management (materials in the entrance stock and materials of unfinished production) in your production system
6. Select the best description of management of stocks of finished products in your production system.
7. Select the best description of Quality Assurance in your production system.
8. Select the best description of Product Lifecycle Management in your production system
9. Select the best description of application of Toyota Production System TPS and Green and Lean Production GALP concept in your production system.

Each answer had a value 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 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.

It was possible to select more than one answer on each question. Depending on selected answer(s), an overall score for each question was calculated as average value of all selected answers and their scores.

On Figure 2 an overall results of questionnaire, like industrial maturity level of Croatian manufacturing industry, are presented.

Analysis of interviews with CEOs

Second step was to select best enterprises and make interviews with their CEOs and technical directors. More than 50 interviews were made in 38 enterprises. Basic elements of enterprise's technique, organization and personnel were analysed. Interviewed CEOs and technical directors rated what elements are most important to them using scale from 0 (irrelevant) to 5 (necessary).

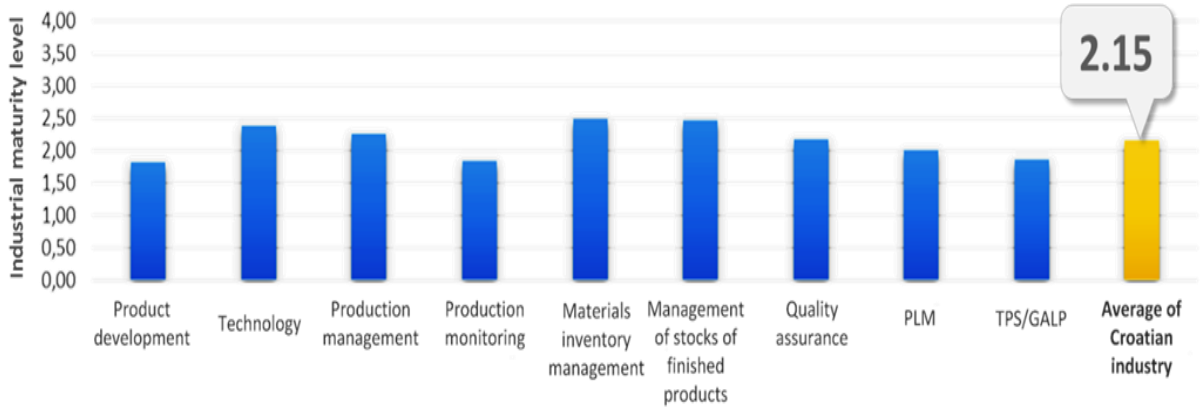

Figure 2 Level of industrial maturity for specific segment of production and average of entire Croatian industry

After selecting the companies that will be analysed, respectively the determination of a set of alternatives, next step is to choose the criteria with which the analysis will be performed. For every enterprise we decided to have three groups of criteria: technique (B1), organization (B2) and personnel (B3). Each of these three groups of criteria has the set of 5 sub-criteria and that can be seen as a hierarchy in Figure 3.

The problem of industrial enterprises evaluation is solved by a model that combines analytical hierarchy process (AHP) [3] and TOPSIS method [4], [5]. The calculations to be made for AHP studies will usually

prove to be fairly complex and they will call for the use of special software packages and in this paper Expert Choice was used.

In every of 38 enterprises pairwise comparisons for the three main criteria were carried out and we obtained 38 different matrices. The elements of final matrix are obtained as geometric mean of these 38 evaluations and it is presented in the Table 1.

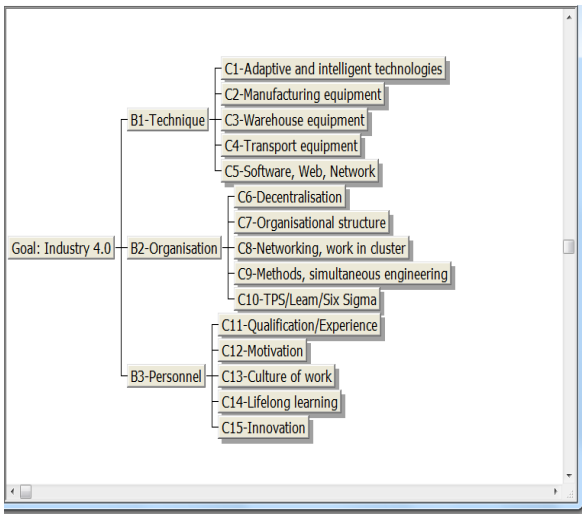

Figure 3 Problem hierarchy

Table 1 Geometric mean for the main criteria

	B1	B2	B3
B1	1	0,801948	0,42125
B2		1	0.515826
B3			1

These data were entered into the software Expert Choice and the weights of these three groups of criteria are obtained (Figure 4.):

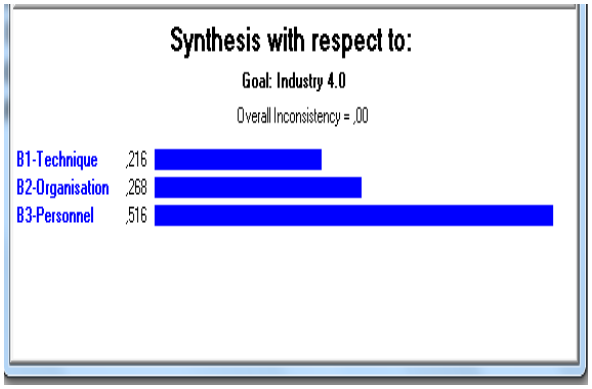

Figure 4 The weights for the main groups of criteria

It can be seen that for the CEO-s most important group of criteria is Personnel, i.e. decision makers think that for the good company (a company that is closest to the concept of industry 4.0) most important is personnel equipment.

Then for each company (i.e. for 38 of them), based on a questionnaire carried out in the project INSENT, mutual comparisons of each sub-criteria group were obtained. Since each group has 5 sub-criteria, for each company three matrix of mutual comparisons are obtained, i.e. Altogether 38 x 3 = 114 different matrices of mutual comparisons.

Thereafter, for each group of sub-criteria (C1 – C5, C6 – C10, C11 – C15) the geometric mean of these 38 matrix elements were calculated (Table 2 – Table 4) and these matrices are entered into software Expert Choice.

Table 2 Geometric means – Technique

	C1	C2	C3	C4	C5
C1	1	0,82844	2,20402	1,93234	0,89929
C2		1	3,01684	2,70905	1,07210
C3			1	0,99460	0,3503
C4				1	0,38009
C5					1

Table 3 Geometric means – Organisation

	C11	C12	C13	C14	C15
C11	1	0,96714	0,91461	1,05580	0,88755
C12		1	0,86417	0,99372	0,83372
C13			1	1,17122	0,9013
C14				1	0,79502
C15					1

Table 4 Geometric means – Personnel

	C11	C12	C13	C14	C15
C11	1	0,96714	0,91461	1,05580	0,88755
C12		1	0,86417	0,99372	0,83372
C13			1	1,17122	0,9013
C14				1	0,79502
C15					1

With the program Expert Choice final weights (importance) for all 15 sub-criteria are obtained and they are presented separately (Figure 5.).

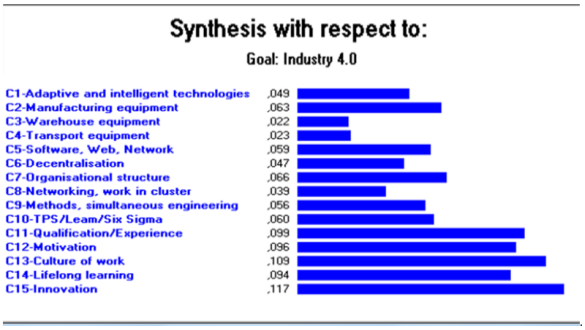

Figure 5 Final criteria weights obtained by Expert Choice

It can be seen that most important criteria are from the third group - Personnel. First is Innovation, then Culture of work and the third is Qualification/Experience.

These are the final values that will be used in TOPSIS method as the criteria weights to get the final ranking of 38 companies. The decision matrix for TOPSIS method (evaluations of all alternatives – companies by all criteria) are obtained from interviewing the CEO's and they gave the evaluations from 1 to 10 points (bigger is better) for all fifteen criteria for their companies.

After the completed calculation in TOPSIS method the final ranking of alternatives was obtained in the sense that higher are ranked those companies whose

characteristics are closer to companies from the industry 4.0, or that are more willing to introduce the industry 4.0 in their business operations.

Final ranking of the companies and their relative closeness indexes obtained by TOPSIS method are presented in Table 5.

Table 5 Final ranking obtained by TOPSIS method

Rank	Enterprises	RCi	Rank	Enterprises	RCi	Rank	Enterprises	RCi
1.	A23	**0.87042**	**14.**	A26	**0.71990**	**27.**	A5	**0.61570**
2.	A16	**0.85921**	**15.**	A11	**0.71894**	**28.**	A18	**0.61142**
3.	A24	**0.82151**	**16.**	A12	**0.71597**	**29.**	A32	**0.60108**
4.	A9	**0.81090**	**17.**	A33	**0.70867**	**30.**	A20	**0.57847**
5.	A19	**0.79977**	**18.**	A4	**0.70783**	**31.**	A22	**0.55989**
6.	A37	**0.79183**	**19.**	A1	**0.70274**	**32.**	A17	**0.54807**
7.	A14	**0.78081**	**20.**	A27	**0.69913**	**33.**	A13	**0.53437**
8.	A25	**0.76565**	**21.**	A2	**0.69758**	**34.**	A6	**0.51982**
9.	A7	**0.76521**	**22.**	A29	**0.67345**	**35.**	A35	**0.50388**
10.	A28	**0.76165**	**23.**	A8	**0.67257**	**36.**	A38	**0.50388**
11.	A21	**0.74197**	**24.**	A31	**0.65908**	**37.**	A15	**0.50334**
12.	A30	**0.72970**	**25.**	A10	**0.63430**	**38.**	A36	**0.46952**
13.	A3	**0.72604**	**26.**	A34	**0.61962**			

3. CONCLUSION

In order to determine the rank of the company in relation to industrial maturity level AHP and TOPSIS methods are used. Considering the three main criteria: technique, organization and personnel as well as the fifteen sub-criteria, thirty-eight enterprises are ranked according to their relative closeness index.

ACKNOWLEDGEMENT

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