RANKING ENTERPRISES IN TERMS OF COMPETENCES INSIDE REGIONAL PRODUCTION NETWORK

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Abstract

Today's economic crisis has led to bankruptcy of many successful, but usually large-sized enterprises. This brought into question the future of large-sized enterprises. However, the only alternative to large-sized enterprises (LEs) is networking of small and medium-sized enterprises (SMEs) into Regional Production Networks (RPNet). RPNet is non-hierarchical organizational form in which every SME is autonomous. Hence, every SME of production network is capable and wiling to be part of special cooperation inside network called Virtual Enterprise (VE). For each new product a new virtual enterprise is formed from different SMEs. The question is: which SMEs will be part of new virtual enterprise? If it is possible to evaluate SME's competences, it is also possible to rank SMEs. Ranking of SMEs according to technical, organizational and human competences is multi-criteria decision analysis (MCDA) problem. So, in this paper PROMETHEE method is selected to perform a ranking of SMEs.

Key words: *Production networks, Competence-cells, PROMETHEE*

1. INTRODUCTION

In today's reality a production-oriented enterprises need to have a high degree of specialization in different narrow fields of work, and, at the same time, a flexible production system that will "listen" and adapt to the needs of customers (a very specific ones, and a wide range ones). This creates a new vision of a modern enterprise which needs to unite the somewhat contradictory requirements:

specialization vs. flexibility. It would therefore be wrong to search for solution within a traditional production system of a large-sized enterprise (LE - Large-sized Enterprise), but the solution lies in the networking of small production systems of small and medium-sized enterprises (SME - Small and Medium-sized Enterprise).

SMEs, which primarily apply new technologies with ease, were recognized by the European Union as the key factors of transformation of the European "knowledge-based economy". According to the EU, the enterprise is classified as SME if: it's independent, have fewer than 250 employees and balance sheet total not exceeding €43 million. In addition, SMEs can be parsed to very small (micro) enterprises having fewer than 10 employees. A further reason of EU investment in SMEs is their share in the total number of enterprises: 99.8% (Figure 1).

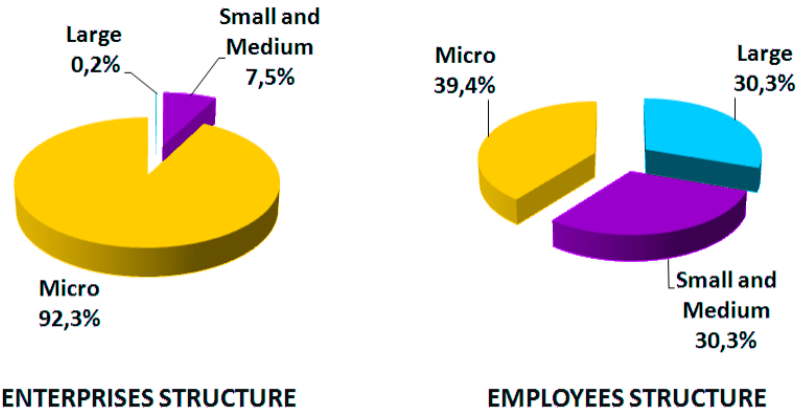

Figure 1: Structure of industrial enterprises in the EU (source: Technical University Chemnitz, 2007)

A particular potential are micro enterprises that have the productivity level of 62% which is up to 25% less than productivity of SMEs (Müller E. et al., 2006). This lack of productivity is primarily classified as unused capacity or lack of work. When it comes to the Republic of Croatia, the structure of industrial enterprises is similar (Figure 2).

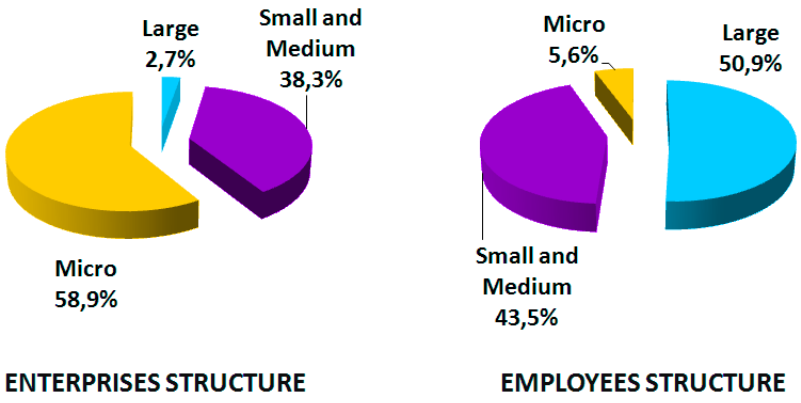

Figure 2: Structure of industrial enterprises in the Republic of Croatia (source: Croatian Bureau of Statistics, 2007)

The conclusion is that the Republic of Croatia is catching up with EU trends in the structure of industrial enterprises, as well as in the structure of their employees. Therefore, the EU strategy for the development of SMEs should begin to apply in Croatia. One of the key strategies of development of SMEs is their networking in the regional co-operation network. Currently the most famous concept is the "Competence-Cell-based Network" developed at the Technical University Chemnitz (Müller E. et al., 2006). This concept is particularly interesting for application in Croatia, since the economy of Croatia has very similar problems with slow recovery from real-socialist production system, like it has ex-Eastern Germany.

2. COMPETENCE-CELL-BASED NETWORK

This concept implies the networking of small and medium-sized enterprises (SMEs) in the non-hierarchical Regional Production Networks (RPNet). Such a network is called competence-cell-based network. Each enterprise represents a single competence-cell, since the employees of each company have a specific set of competencies. However, each competence-cell retains its autonomy, because this network is non-hierarchical. Such a network contains elements of a holistic system, such as for example: ants in nature. Each ant is an autonomous, but all the ants communicate with each other and cooperate for the benefit of the entire ant colony. This is the basic idea of competence-cell-based network. Hence, all enterprise in the network, in addition to already existing co-operation, are willing and able to develop new co-operations on new projects - new product development. This is shown on Figure 3 for one fictive simple competence-cell based network.

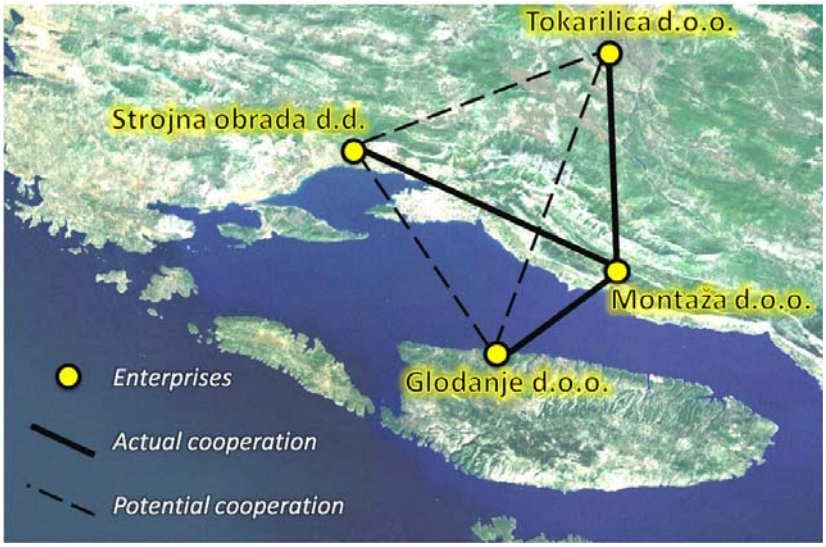

Figure 3: Example of fictive simple competence-cell-based network

There are several types of competence-cells (Müller E. et al., 2006) which represent essential elements of the value adding process: marketing, product development, production planning, production, assembly, quality and service. According to this concept all of the above mentioned competence cells communicate with each other using a special Web portal. Although Müller et al. differ several types of competence-cells; this paper will be limited only to the competence-cells for production and assembly. The aim is to choose optimal combination of them in order to setup a new Virtual Enterprise to produce a new product.

3. THE PROBLEM OF THE SELECTION OF COOPERATORS

The problem of the selection of cooperators (partners) arises when the production process is parsed to technology processes that need to be done to produce a product. In fact it is very likely that the same technological process can be done by two or more different cells (enterprises) in the network. The question is: which enterprise to choose (Fischer M. et al., 2004). Therefore, it is obvious that, before the selection process, enterprises need to be evaluated (on the basis of their performances and competences). In this way, enterprises with the highest rating will be selected and they will form new Virtual Enterprise.

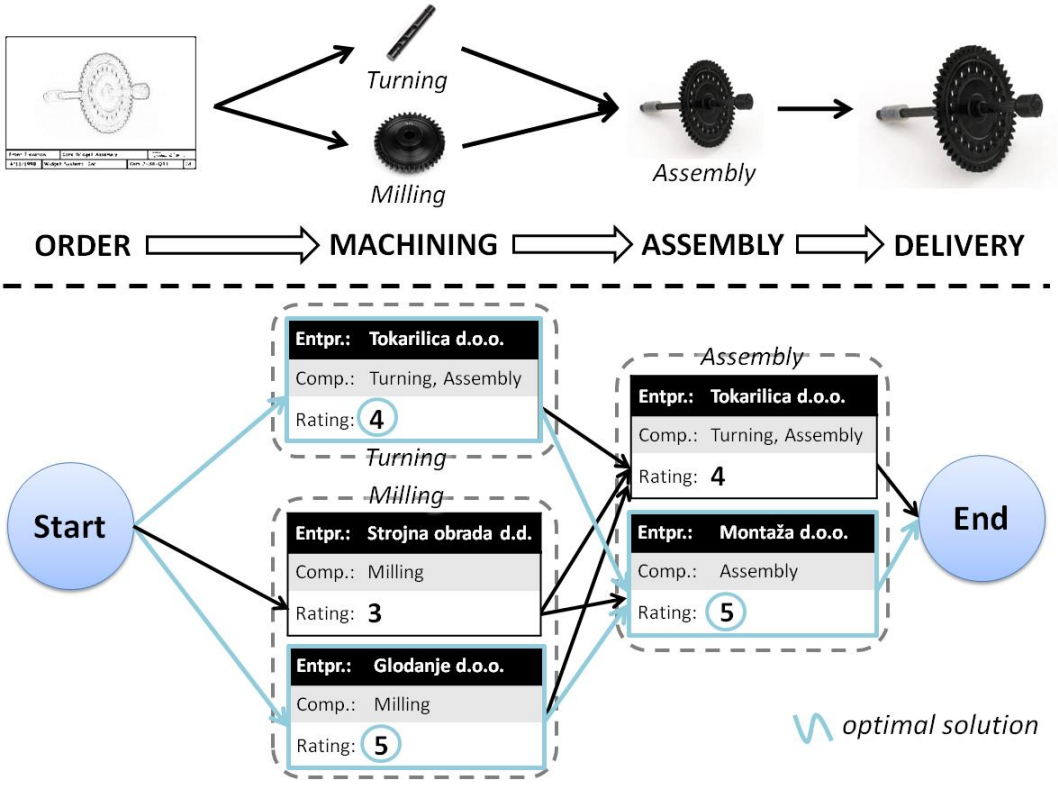

Figure 4: Production process with possible alternatives and optimal solution

Figure 4 shows a production problem, i.e. a production process with possible alternatives, and its optimal solution (Mladineo M., Veza I., Corkalo A., 2011). The problem can be presented as a network graph that has a beginning or source (order) and end or drain (delivery). The network is formed of competence-cells (enterprises), and each technological process is presented by cells that can perform it. Each enterprise has its rating. Higher rating is better. According to Figure 4, for each technological process (turning, milling or assembly) a cell (enterprise) with higher rating is selected. Hence, the production process will be realized using best combination of enterprises. The combination of enterprises is one new Virtual Enterprise.

However, the evaluation of enterprises performances is needed to select the optimal combination of them (Agarski B. et al., 2012). Since, the evaluation of enterprises performances is multicriteria problem; a special multiple criteria decision analysis (MCDA) method is used: PROMETHEE method (Brans J.P., Mareschal B., Vincke P.H., 1984).

4. PROMETHEE METHOD

The problem of the selection or the ranking of alternatives submitted to a multicriteria evaluation is not an easy problem. Usually there is no optimal solution; no alternative is the best one on each criterion. In the recent years several decision aid methods or decision support systems have been proposed to help in the selection of the best compromise alternatives. In this paper the PROMETHEE method (Preference Ranking Organisation METHod for Enrichment Evaluations) was chosen because this method is known as one of the most efficient, but also as one of the most transparent method for MCDA.

An input for PROMETHEE method is a matrix consisting of set of potential alternatives (actions) A, where each a element of A has its $f_j(a)$ which represents evaluation of criteria j (Figure 5). Each evaluation $f_j(a_i)$ must be a real number.

	$f_1(.)$ $f_2(.)$ …… $f_j(.)$ …… $f_k(.)$
a_1 a_2 … a_i … a_n	$f_j(a_i)$

Figure 5: Input matrix for PROMETHEE method

Method PROMETHEE I ranks actions by a partial pre-order, with the following dominance flows:

$$\text{leaving flow:} \quad \Phi^+(a) = \frac{1}{n-1}\sum_{x\in A}\pi(a,x)$$

$$\text{entering flow:} \quad \Phi^-(a) = \frac{1}{n-1}\sum_{x\in A}\pi(x,a)$$

where a denotes a set of actions, n is the number of actions and π is the aggregated preference index defined for each couple of actions. The PROMETHEE I method gives the partial pre-order. A net outranking flow is obtained from PROMETHEE II method which ranks the actions by total pre-order:

$$\Phi\ (a) = \Phi^+(a) - \Phi^-(a)$$

In the sense of priority assessment net outranking flow represents the synthetic parameter based on defined criteria, priorities among criteria and criteria weights. Additionally, different sets of criteria weights can be used and then each set represents one scenario. Usually MCDA problems have more than one scenario.

5. RANKING OF ENTERPRISES COMPETENCES

5.1. Criteria determination

To rank enterprises of the RPNet it is necessary to design a set of criteria that will represent all the important parameters which need to be taken into account when performing ranking. It should be primarily taken into account that there are parameters that change each time when a new production network is formed for a new product, and there are parameters that do not change so often. Therefore, a set of criteria which will be used can be divided into two sets (Mladineo M., Takakuwa S., Gjeldum N., Veza I., 2011):

- **Dynamic criteria** – criteria whose values change for each enterprise depending upon the offer for particular product production or development (an example of such criteria is the price of the product).
- **Static criteria** – criteria whose values do not change so often, or at most a few times a year (an example of such criteria is a technology of enterprise).

A set of dynamic criteria includes offer that enterprise offered when a new production network for a new product is formed. That offer is usually made up of two elements: the price per piece and the day of delivery. Static set of criteria can be further divided onto :

- **Competence criteria –** criteria covering all the competencies of the enterprise: technical, organizational and human competence.
- **Economic criteria –** criteria that consider economic feasibility or risk of involving enterprise into production network.
- **Sociological criteria –** criteria which analyze sociological impact of involving certain enterprise in the production network.

5.2. Criteria weights and scenario determination

Weighting factors of criteria (criteria weights) make the strongest effects on results of PROMETHEE method. Since it is logical that technology assessment and neatness of settling financial obligations cannot have equal influence on the ranking of enterprises, different weighting factors are used for

these criteria. However it is possible to use multiple sets of different weight factors, so called: scenarios. Each scenario represents a set of criteria weights. In this case, different scenarios can be used for different levels of product complexity and/or production complexity. Complexity of the product is affected by (Mladineo M., Takakuwa S., Gjeldum N., Veza I., 2011):

- Number of parts from which product is made.
- The degree of mutual integration of parts, i.e. level of complexity of assembly.
- The level of complexity of the product and its parts from the aspect of material, shape and size.

and production complexity is affected by:

- Total number of technological processes necessary to make a product.
- Required number of different types of technological processes.
- The level of complexity of required technological processes.
- Size of series.

So it is very difficult to measure the overall complexity of product and/or production.

		Product complexity	
		Simple	Complex
Size of series	Small	Scenario A	Scenario B
	Large	Scenario C	Scenario D

Figure 6: Different scenarios for different complexity of product and/or production

However, a measure of the overall complexity of the product and/or production, or the degree of product complexity and/or production, is what defines which scenario to use. So scenario portfolio was made for different product complexity and size of series (Figure 6).

5.3. Ranking of enterprises

An input matrix for PROMETHEE method, i.e. criteria evaluation for each action (enterprise), is made using data gathered in special questionnaire. This questionnaire was sent to the production enterprises of Split-Dalmatia County. In the following figures (Figure 7 and Figure 8) an input matrix for 7 enterprises is shown. However, star names are used instead of real names of enterprises.

		Dynamic criteria		Static criteria						
				Competence criteria						
ID	Name	Price per piece	Delivery day	Technology	References	Information system	Employees qualification	Employees specialist level	Quality certificate	Continuous improve-ment
		Minimum	*Minimum*	*Maximum*	*Maximum*	*Maximum*	*Maximum*	*Maximum*	*Maximum*	*Maximum*
		€	*Day*	*0-5 grade*	*0-5 grade*	*0-5 grade*	*0-6 grade*	*0-5 grade*	*0 - 1 (no - yes)*	*0-5 grade*
1	Alpha Centauri	103	31	4	1	1,5	2	4	1	1
2	Beta Ursae Minoris	102	33	4	2	1	3	3	1	1
3	Alpha Ophiuchi	110	33	4	3	0,5	3	0	1	1
4	Beta Aquarii	115	35	4	4	2	4	2	1	1
5	Alpha Orionis	116	32	3	2	0,5	3	4	1	1
6	Alpha Virginis	111	33	4	1	1,5	3	3	1	1
7	Delta Leonis	100	35	2	2	3,5	2	2	0	2

Figure 7: Input matrix for dynamic and competence criteria

		Static criteria				
		Economic criteria			Sociological criteria	
ID	Name	Deadline reliability	Network cooperation	Financial reliability	Number of employees	Area of special state care
		Maximum	*Maximum*	*Maximum*	*Maximum*	*Maximum*
		0-5 grade	*0-5 grade*	*0-5 grade*	*Employee*	*0 - 1 (no - yes)*
1	Alpha Centauri	5	2	5	90	0
2	Beta Ursae Minoris	4	3	4	300	0
3	Alpha Ophiuchi	5	0	5	30	1
4	Beta Aquarii	5	3	5	25	0
5	Alpha Orionis	4	3	4	190	0
6	Alpha Virginis	5	1	5	80	0
7	Delta Leonis	4	1	4	1300	0

Figure 8: Input matrix for economic and sociological criteria

PROMETHEE method was performed using 4 different predefined scenarios. A set of weights for each scenario was determined by experts. Criteria preference function type and preference thresholds where obtained using in-built function *"Preference Function Assistant"* of *Visual PROMETHEE* software, developed by Bertrand Mareschal at ULB, Bruxelles (http://www.promethee-gaia.net/). Following results where obtained (Figure 9).

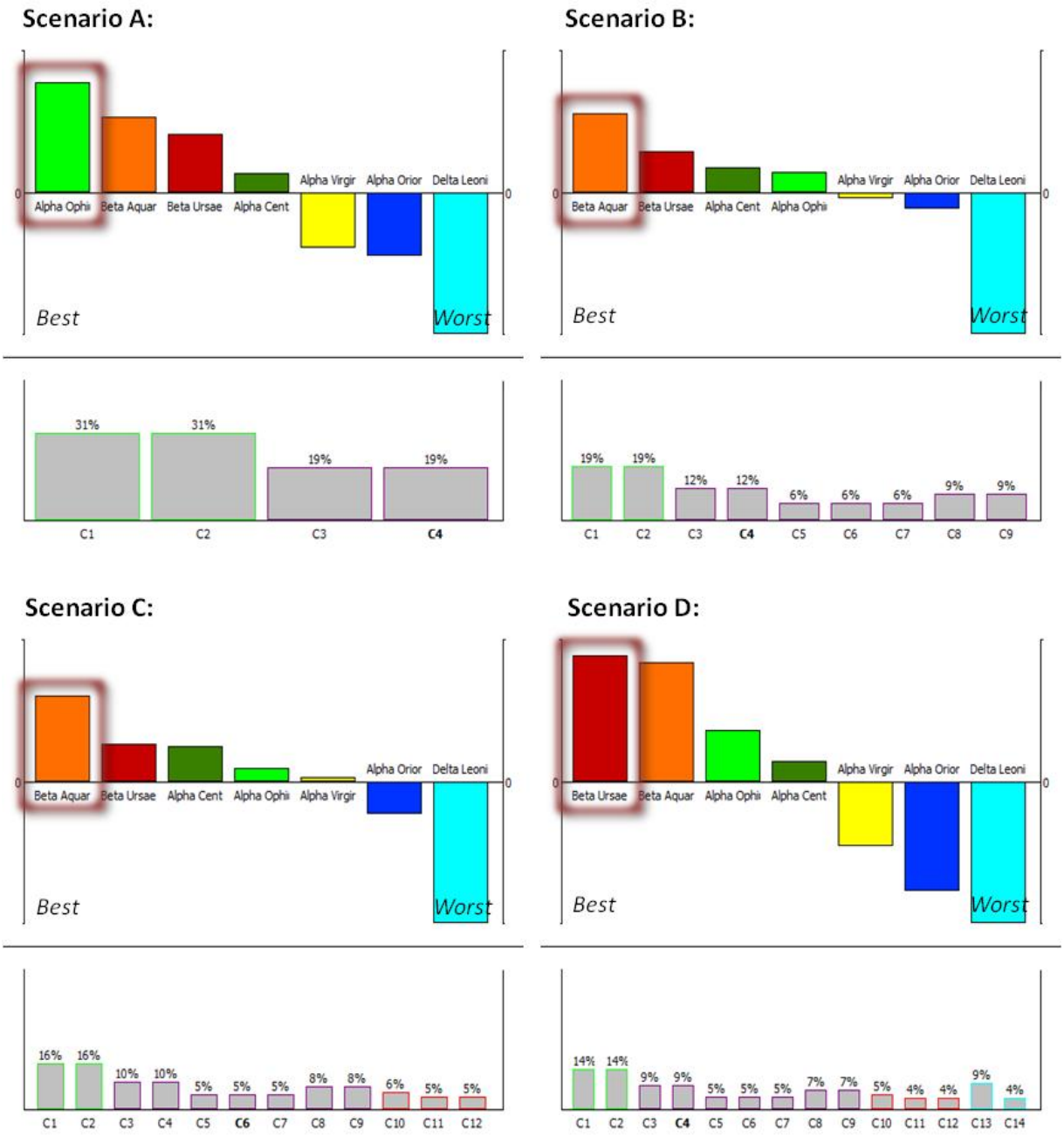

Figure 9: Ranking results and criteria weights for each scenario

This analysis showed that 3 enterprises (*Beta Ursae Minoris*, *Alpha Ophiuchi* and *Beta Aquarii*) are dominant in comparison with other enterprises. However, in different scenarios these 3 enterprises are taking turns at the top. For example: for simple product and small series the best enterprise to realize that production process is *Alpha Ophiuchi*. However, for complex product and large series the best enterprise to realize that production process is *Beta Ursae Minoris*.

6. CONCLUSION

This paper demonstrated unique decision support system for ranking and evaluation of enterprises inside regional production network. It is clearly shown that, using PROMETHEE method, enterprises can be evaluated taking into account their competences, i.e. what enterprise posses in the terms of technology, references, information system, etc. Hence, economic and sociological criteria can also be added into analysis.

A special scenario portfolio was created for different complexity of product and/or production process. On the case study with real enterprises, it is shown that different scenarios will produce different enterprise as the best one. So it is very important for production network manager to carefully choose criteria weights and form proper scenarios. This could be done by interviewing experts.

Further research will be made in expanding scenario portfolio 2x2 matrix to 3x3 or 4x4. Stability intervals analysis will be made for criteria weights to determine weights set is the most stable one.

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