

MULTI CRITERIA DECISION MAKING MODEL FOR LOGISTICS PROCESSES IN PARTICULAR ENTERPRISE

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Abstract: Relevant indicators and measurement methods should be assessed in order to contribute to optimize management of an enterprise. Business performance can be measured by various indicators and various business results could be assessed. Analyses of value chains should be focused on specification of so called bottle necks which mention those activities that disable to increase business margin. At the same time, these analyses show the inefficiency caused by oversized of some activities regarding to lower level of assurance or safety and lower performance of other business activities. Importance of multi criteria decision-making methods for evaluation of alternatives doesn't lie in definite increasing of results objectivity although it should lead to that. Priority of this method lies mainly in simplification of manager's decision making. It allows managers to arrange alternatives according to extensive file of criteria, it describes particular steps of solution and its logical sequence, this methodology also requires from managers to express their understanding of various criteria importance. All this process of solution is transparent, repeatable and there are evident starting assumptions and also how these assumptions, situations, criteria and incidents affect reached results.

Keywords: decision making, multi criteria methods, purchasing logistics, optimization

1. INTRODUCTION

Complexity, extensiveness and variability of contemporary technical, social respectively combined objects requires application of such a methods that allow explicitly and objectively to handle, to project and further to manage those features which characterize synthesis of functional parts into one unit.

Requirements on systemic model can be gathered into the following items. So, for the systemic model it is necessary:

- to reflect systemic features of an object, so it means to take into account all parts, events and processes of an object which share on the generation of these features,
- to simplify primary complexity of an objection order to be technically managed,

- to unify model heterogeneity of particular parts of an object and by that to allow application of formalized tools,
- that the form of a model could allow quantification and metrics of monitored parameters.

Systemic features are universal features of the objects from real life. This term contains the following features of the objects:

- interaction the parts of a unit among themselves,
- interaction of the object with an environment,
- dynamics and goal focus of the object behaviour,
- adaptability of the object on environmental changes and inside the particular object,
- ability to save and to utilize experiences.

2. METHODOLOGY

A choice of the process is managed by input setting and by internal assumptions. Petri Nets (PN) are suitable tools which can be characterized by the following description. Net is created by two kinds of peaks:

- traditional set of peaks which describes status parameters – it means elements (situations) of a system,
- untraditional set of peaks which describes transitions between various statuses of two near-by elements, respectively it causes the change of a status in the following element caused by the impact in the previous element.

Transition (element from the non-standard set of elements) differs from situations. It is not associated as a one element feature but it is independent element like virtual item which initiates situation. It is also presentation of dynamic feature of a connection within the system structure. Transition is real holder of the element ability to change its status. Report of the system structure is completed by modification of incident function (Lakehal and Tachi, 2018; Zhang et al., 2011):

- connections which describe relation from the element to the transition – “transition” incident functions,
- connections in opposite direction, it means coming from element back to transition (to that which caused the change of given element) – “feedback” incident functions.

On the base of the above mentioned process, Petri Nets can be described:

$$PN = \{P, T, F, B, M_o\} \quad P \cap T = \emptyset \quad (1)$$

where: P, T - related sets of elements and transitions,
 F, B - incident transition and feedback functions,
 M_o - initial system line-up.

Implementation of transition and feedback incident functions allow to divide investigation of how elements are prepared for the realisation of transitions (matrix F) or how elements are prepared to accept incidents of transitions (matrix B). Both matrixes can be joined into one matrix E.

$$E \subseteq (PxT) \cup (TxP) \quad (2)$$

Logistics systems in wood-processing manufacturing are dynamic, with permanent adaptation to turbulent market environment and they integrate all functions of material management, starting with assessment of material and resources demands and ending with selling of final products.

Multi-Attribute Utility Theory (MAUT) (Fishburn, 1967; Keeney, 1977) was the most commonly utilized multi-criteria decision making (MCDM) method. MAUT is essentially an extension of Multi-Attribute Value Theory (MAVT) (Keeney, 1974) and is “a more rigorous methodology for how to incorporate risk preferences and uncertainty into multi criteria decision support methods” (Loken, 2007). Earlier research in MAUT compared it to then-current MCDM methods. In the last decade, various authors have become to use MAUT in order to assist decision analysis in real-world problems. Canbolat, Chelst, and Garg (2007) applied a MAUT model to assist in selecting the location of a global manufacturing facility. MAUT was utilized due to its common use in natural resource management problems. Their approach centered around societal risk preferences and they utilized a survey to obtain and examine desirable attributes. Gomez-Limon, Arriaza, and Riesgo (2003) utilized multi-criteria decision making analysis in regards to risk aversion. MAUT is an expected utility theory that can decide the best course of action in a given problem by assigning a utility to every possible consequence and calculating the best possible utility (Konidari and Mavrakis, 2007). The major advantage of MAUT is that it takes uncertainty into account.

Analytic Hierarchy Process (AHP) is a method similar in popularity to MAVT/MAUT is the Analytic Hierarchy Process (Saaty, 1980). For MAUT and AHP, “the two methods rest on different assumptions on value measurements and AHP is developed independently of other decision theories. The major characteristic of the AHP method is the use of pair-wise comparisons, which are used both to compare the alternatives with respect to the various criteria and to estimate criteria weights” (Loken, 2007).

It is one of the more popular methods of MCDM and has many advantages, as well as disadvantages. One of its advantages is its ease of use. Its use of pairwise comparisons can allow decision makers to weight coefficients and compare alternatives with relative ease. It is scalable, and can easily adjust in size to accommodate decision making problems due to its hierarchical structure. And although it requires enough data to properly perform pairwise comparisons, it is not nearly as data intensive as MAUT. The method has experienced problems of interdependence between criteria and alternatives. Due to the approach of pairwise comparisons, it can also be subject to inconsistencies in judgment and ranking criteria and it “does not allow [individuals] to grade one instrument in isolation, but in comparison with the rest, without identifying weaknesses and strengths” (Konidari and Mavrakis, 2007).

Fuzzy Theory (Zadeh, 1965) has existed now for several decades. Fuzzy logic itself has proven to be an effective MCDM method. Khadam and Kaluarachchi (2003) addressed the use of cost-benefit analysis as the primary method for decision analysis when addressing environmental projects.

Fuzzy set theory is an extension of classical set theory that “allows solving a lot of problems related to dealing the imprecise and uncertain data” (Balmat, 2011). It has many advantages. Fuzzy logic “takes into account the insufficient information and the evolution of available knowledge” (Balmat, 2011). It allows imprecise input. It allows for a few rules to encompass problems with great complexity. For disadvantages,

fuzzy systems can sometimes be difficult to develop. In many cases, they can require numerous simulations before being able to be used in the real world. Fuzzy set theory is established and has been used in applications such as engineering, economic, environmental, social, medical, and management. Many of these types of problems take advantage of the availability of imprecise input.

Simple Multi-Attribute Rating Technique (SMART) is one of the simplest forms of MAUT. It requires two assumptions, namely "utility independence and preferential independence" (Chen et al., 2010). This method conveniently converts importance weights into actual numbers. Major advantages of SMART, in addition to those described in MAUT, are that it is simple to use and it actually allows for any type of weight assignment techniques (i.e., relative, absolute, etc.). It requires less effort by decision makers than MAUT. It also handles data well under each criterion. SMART's common applications are in construction, transportation and logistics, military, manufacturing and assembly problems. Its ease of use helps in situations where a fair amount of information is available and access to decision-makers is easy to obtain. Its simplicity appears to be what keeps this method fairly popular.

Case-Based Reasoning (CBR) is a multi-criteria decision making method that retrieves cases similar to a problem from an existing database of cases, and proposes a solution to a decision-making problem based on the most similar cases (Daengdej et al., 1999). This provides the first of its advantages, which is that it requires little effort in terms of acquiring additional data. It also requires little maintenance as the database will already be existing and requires little upkeep. One major advantage that it has over most MCDM methods is that it can improve over time, especially as more cases are added to the database. It can also adapt to changes in environment with its database of cases.

3. RESULTS AND DISCUSSION

Customers behaviour can be characterized by the uncertainties in the quality, quantity and time demand of particular product. According to Song and Hong (2008), in a time of globalization and an increasingly competitive environment, measuring performance has become critical to business success. From Kanji (2002), the first condition to improve and to achieve business excellence, is to develop and implement a system for performance measurement (PMS). The term performance measurement is defined as the process of quantifying the efficiency and effectiveness of actions (Neely, 2002). The literature presents the following popular performance measurement frameworks, such as, performance measurement matrix, Balanced Scorecard (BSC), performance pyramid, Sink and Tuttle framework, European Foundation for Quality Management (EFQM) excellence model, performance prism (PP), and lastly, the Malcolm Baldrige National Quality Award (MBNQA) model, to name just a few. These performance measurement frameworks provide the following: a balanced view between an external and internal focus (Keegan et al., 1989); results and determinants (Fitzgerald et al., 1991); the four perspectives of the BSC (Kaplan and Norton, 1992); and, finally, the multiple perspectives of the stakeholders of PP (Kennerley and Neely, 2000). Application of PMS can be described through three factors: decision support, work integration and communication. Decision support factor concerns the extent to which the PMS is used for problem solving, data, causality and relationships analyzing. Second factor explains and justifies decisions and the third factor tries to improve the effectiveness of decision making process. It is

also necessary to allocate responsibilities and decisions, and set the goals of performance. The quantification of performance measurement is closely defined by multi criteria decision-making methods. So that a PMS can be characterized as a multi-criteria tool, made from a set of metrics. Many enterprises are aware that the management of logistics needs a clear PM methodology. Therefore our research focuses on the area of metrics, decisions and criteria within the supply chain and material flow of particular woodprocessing enterprise.

Supply chain model

It had been decided to solve supply chain by the model of Petri Nets. This tool is suitable because it expresses decision situations, describes the whole material flow and because of parametrization and quantification of criterions expressed by transitions and elements (situations). It can be used use also other methods, like CPM, PERT, Gantt chart. These methods could be used mainly for the planning, co-ordination and time spending description of particular processes.

Knot P1, place – warehouse of logs

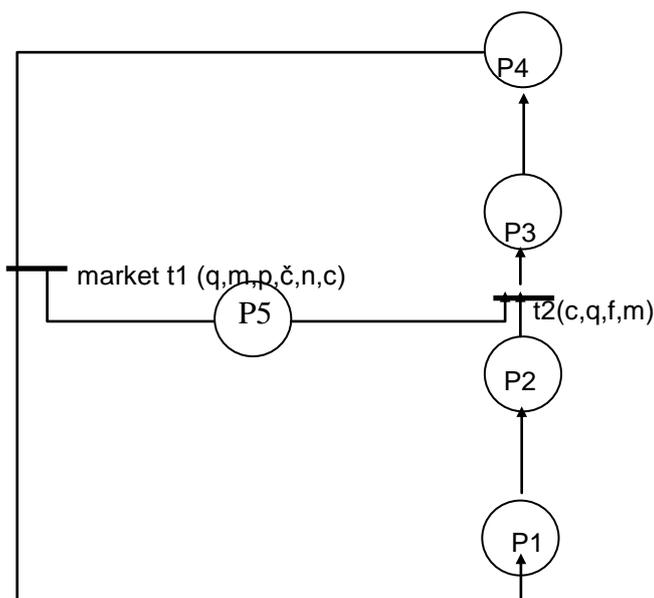
The first knot of the chain is warehouse of logs. It can be seen that there is no transition “t” before this knot. Inputs must be bought in the market from external supplier. Of course, it is necessary to make choice among suppliers what has further impact on the quality of production and final product. It is necessary to assess some specific demanded parameters on inputs (wood raw or logs) in order to monitor and evaluate this process of warehousing.

Knot P2, place – manipulation and debarking

Every log which is moved to saw mill has to go through this place. Again, it must be assessed parameters of the process in order to monitor it, to evaluate it and to control it. Proposal is given in the following Table 2.

Knot P3, place – saw mill

Before the entry of logs into saw mill, it is a transition „t₂” where it is necessary to decide about the choice of logs. It is possible to take them from own capacity after the flow through the previous two operations or to buy debarked logs from external supplier. This choice depends on the meeting particular technological and economic criteria.



$P = (P_1, P_2, P_3, P_4, P_5)$
 $T = (t_1, t_2)$

P_4 - timber warehouse,
 P_3 - saw
 P_2 - manipulation and debarking
 P_1 - warehouse of logs
 P_5 - supplier of logs

Fig. 1. Model of logistics (supply) chain within the division of timber production (Aláč, 2005)

Table 1

Criteria for the monitoring of knot "Warehouse of logs"

Criteria	Agree	Disagree
Volume	over $X \text{ m}^3$	below $X \text{ m}^3$
Time of order	X days	less or more than X days
Safety stock	$X \text{ m}^3$	below $X \text{ m}^3$
Qualitative requirements	given by the standard	other than in standard
Inventory costs	over $X \text{ €}$	over $X \text{ €}$

Table 2

Criteria for the monitoring of manipulation and debarking process

Criteria	Agree	Disagree
Diameter \varnothing	between X - Y cm	Out of interval X - Y cm
Time of the process	X min	X min
Length of a log	between X - Y m	Out of interval X - Y m
Costs	below $X \text{ €}$	Over $X \text{ €}$

Table 3

Decision making matrix of the transition „ t_2 “ - Saw mill

Criteria	Weight (importance) (w)	Own supply	External supply
Price (c)	w1	$X \text{ €}$, respectively given as a lower or higher than from external supplier	$X \text{ €}$, respectively given as a lower or higher than from internal supplier
Quality (q)	w2	Standard	Standard
Flexibility of a supply (f)	w3	Over or below X days, hours	Over or below X days, hours
Supplied volume (m)	w4	Over or below $X \text{ m}^3$	Over or below $X \text{ m}^3$

Table 4

Final decision matrix for the transition "Saw mill"

Criteria	Weight (importance) (v)	Own supply	External supply
Price	w1	X points	Y points
Quality	w2	X points	Y points
Flexibility of a supply	w3	X points	Y points
Supplied volume	w4	X points	Y points
Total utility		$\sum X.v$	$\sum Y.v$

Table 5

Decision matrix of transition "Saw mill" of the choice between external suppliers

Criteria	Weight (importance) (v)	External supplier No.1	External supplier No.2
Price	w1	X €, respectively given as a lower or higher than from external supplier No.2	X €, respectively given as a lower or higher than from external supplier No.1
Quality	w2	given by the standard	given by the standard
Flexibility of a supply	w3	Over or below X days, hours	Over or below X days, hours
Supplied volume	w4	Over or below X m ³	Over or below X m ³

The most important operation within the timber manufacturing is cutting. It is very important to deal with the selection, evaluation and monitoring of criteria which have impact the quality of this process. It should be necessary to monitor not only yield of the cutting and quality of a timber, but it is necessary to focus on costs and time of given process because these parameters highly affect satisfaction of a customer.

Table 6

Criteria for the monitoring of cutting process

Criteria	Agree	Disagree
Yield	X %	less than X %
Time of the process	X mins	more than X mins
Timber quality	given by the standard	deviation from the standard
Costs of the process	Less than X €	More than X €

Knot P4, place – timber warehouse

The last knot in the logistics chain is timber warehouse. Company uses own warehouses with sufficient free space. All products are made only for concrete order. Every product must meet particular qualitative parameters given by the standard and these should be monitored and controlled also in the final products warehouse. Except of qualitative parameters it should be suggested also others like it is given in the following Table 7. Because of the simplification of the timber selection system had been used only 3 qualitative classes. Of course, this simplification did not impact presented results.

Table 7

Criteria for the monitoring of knot "Timber warehouse" and transition t_1 "market"

Criteria	Class 1	Class 2	Class 3
quality (q)	given by the standard	given by the standard	given by the standard
Produced volume (per 1 day, per 1 shift, per 1 order) (m)	m ³	m ³	m ³
% from the total volume (per 1 day, per 1 shift, per 1 order) (p)	X %	X %	X %
Average production time for the 1 m ³ (č)	X hrs		
Costs (c)	X €	X €	X €

4. CONCLUSION

Proposed model of logistics chain is the complex of application the various methods. Proposed model could be suitable tool for the supply chain management. Management can be described as a sequence of decisions which are made on the base of information about managed system. There are important quality and objectivity of reached information which should support decision-making process. So, the question is not whether to decide or not but how to decide and which criteria are important. An important part of decision making process is methodology and evaluation of information.

Traditional procedure of decision making process was solved only intuitive and on the base of experiences and professional feeling for given situation. But, at the same time, the intuitive decision making should also lead to very good results but this decision does not take into account feedback from qualitative part of decisions. When the problems occurred it is very hard to choose particular step where the problem was occurred and what did occur it. Intuitive decision making is more subjective. The above mentioned methods should decrease the subjectivity and it could lead to better performance measurement. One of the most important assumption for managers in is to quantify results and to think in alternatives. All these above mentioned methods are helpful for parameters quantification and for alternative thinking of managers.

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REFERENCES

- Aláč, P., 2005. *Viackriteriálne rozhodovanie v logistickom reťazci drevárskeho podniku*. PhD thesis. TU vo Zvolene, Drevárska fakulta, 137 p.
- Balmat, J., Lafont, F., Maifret, R., Pessel, N., 2011. *A decision-making system to maritime risk assessment*. Ocean Engineering, 38(1), 171-176.
- Canbolat, Y., Chelst, K., Garg, N., 2007. *Combining decision tree and MAUT for selecting a country for a global manufacturing facility*. Omega, 35(3), 312-325.
- Chen, Y., Okudan, G., Riley, D., 2010. *Decision support for construction method selection in concrete buildings: Prefabrication adoption and optimization*. Automation in Construction, 19(6), 665-675.

- Fishburn, P., 1967. *Conjoint measurement in utility theory with incomplete product sets*. Journal of Mathematical Psychology, 4(1), 104-119.
- Fitzgerald, L., Johnston, R., Brignall, T. J., Silvestro, R., Voss, C., 1991. *Performance measurement in service businesses*. Chartered Institute of Management Accountants, London, UK.
- Flint, D., J., Larsson, E., Gammelgaard, B., Mentzer, J.T., 2005. *Logistic Innovation: A customer value-oriented social process*. Journal of Business Logistics, 26(1), 113–147, DOI: 10.1002/j.2158-1592.2005.tb00196.x, ISSN 0735-3766.
- Gibson, B.J., Mentzer, J.T., Cook, R.L., 2005. *Supply Chain Management: The Pursuit of a Consensus Definition*. Journal of Business Logistics, 26, 17–25, DOI: 10.1002/j.2158-1592.2005.tb00203.x.
- Gomez-Limon, J., Arriaza, M., Riesgo, L., 2003. *An MCDM analysis of agricultural risk aversion*. European Journal of Operational Research, 151(3), 569-585.
- Jeetendra, V. A., Krishnaiah Chetty, O. V., Prashanth Reddy, J., 2000. *Petri nets for project management and resource levelling*. The International Journal of Advanced Manufacturing Technology, 16(7), 516-520.
- Kahneman, D., 2012. *Myšlení rychlé a pomalé*. Jan Melvil publishing Brno, s.r.o., ISBN 978-80-87270-42-4, 542 p.
- Kanji, G.K., 2002. *Performance measurement system*. Total Quality Management, 13(5), 715–728.
- Kaplan, R., S., Norton, D.P., 1996. *The balanced scorecard: Translating strategy into action*. Harvard Business School Press, Boston, MA.
- Keegan, D.P., Eiler, R.G., Jones, C.R., 1989. *Are your performance measures obsolete?* Management Accounting, 70(12), 45–50.
- Keeney, R., 1977. *The art of assessing multiattribute utility functions*. Organizational Behavior and Human Performance, 19(2), 267-310.
- Kennerley, M., Neely, A. D., 2000. *Performance measurement framework -A review. In Performance measurement-Past, present and future*. Proceedings of the 2nd international conference on performance measurement. Cambridge, UK, 19–21 July.
- Khadam, I., Kaluarachchi, J., 2003. *Multi-criteria decision analysis with probabilistic risk assessment for the management of contaminated ground water*. Environmental Impact Assessment Review, 23(6), 683-721.
- Konidari, P., Mavrikis, D., 2007. *A multi-criteria evaluation method for climate change mitigation policy instruments*. Energy Policy, 35(12), 6235-6257.
- Lakehal, A., Tachi, F., 2018. *Probabilistic Assessment of Road Risks for Improving Logistics Processes*. MATEC Web of Conferences 183, 01003, DOI: 10.1051/mateccconf/201818301003.
- Langevin, A., Riopel, D., 2005. *Logistics Systems – Design and Optimization*. Springer, ISBN 0-387-24971-0, 387.
- Liu, R., Kumara A., Van der Aalst, W., 2007. *A formal modelling approach for supply chain event management*. Decision Support Systems 43, 761-778.
- Loken, E., 2007. *Use of multi-criteria decision analysis methods for energy planning problems*. Renewable and Sustainable Energy Reviews, 11(7), 1584-1595.
- MacBryde, J., Radnor, Z., Shepherd, C., Günter, H., 2006. *Measuring supply chain performance: current research and future directions*. International Journal of Productivity and Performance Management, 55(3/4), 242-258, ISSN: 1741-0401.

- Neely, A., 2002. *Business performance measurement*. Cambridge University Press, Cambridge, MA.
- Saaty, T., 1980. *The analytic hierarchy process: Planning, priority setting, resource allocation*. McGraw-Hill, New York.
- Song, C., Hong, Z., 2008. *Time scorecard: an integrative performance measurement framework for time-based companies*. In 4th International conference on wireless communications, networking and mobile computing (pp. 1–5). Dalian, China, 12–14, October.
- Zadeh, L., 1965. *Fuzzy sets*. *Information and Control*, 8(3), 338-353.
- Zhang, X., Lu, Q., Wu, T., 2011. *Petri-net based applications for supply chain management: an overview*. *International Journal of Production Research*, 49(13), 3939-3961.