THE PROBLEMS OF MEASURING EFFICIENCY IN LOGISTICS

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Abstract: *The efficiency is one of the key factors of company success. The importance of efficiency in logistics is recognized in literature and practice. In the efficiency measurement process different problems appear. Complexity and interdependence of logistics activities cause different problems like: indicator selection problem, conflicting goals, common resource problem, decomposition problem, etc. The mentioned problems are present on each measurement level: supply chain efficiency, logistics systems efficiency, logistics subsystem efficiency, logistics activity efficiency, etc. This paper gives the opportunities for overcoming mentioned problems. The proposed model is based on the Data Envelopment Analysis and the Principal Component Analysis methods. The case study results show that proposed model successfully overcome identified problems.*

Keywords: *Efficiency, Logistics systems, Distribution Centres, PCA – DEA.*

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1. INTRODUCTION

One of the most important engineering tasks is system design and process planning. Using different methods, techniques and knowledge engineers make variety of strategic, tactical and operational decisions. When the system is designed and the parameters are defined, it is necessary to quantify the operating effects (performances). Depending on industries and types of systems, there is a number of different performances. One of the basic and frequently used performances is efficiency. Efficiency is a very important indicator of companies' operations analysis.

There is no universal and generally accepted definition of the efficiency. Different authors define efficiency in different ways. The effectiveness is defined as the level of the goals accomplishment ("doing the right things"), while the efficiency represents the accomplishment of these goals in the best possible way ("doing the right things in the right way") [4]. In the past, both in the literature and in the practice, the greatest attention was paid to the operational efficiency.

The efficiency measurement process in manufacturing companies is completely different from the efficiency measurement process in the service companies. Raw materials and components in production process are transforming in final product. Tangibles and easy measurability of the final product, and resource usage greatly facilitate the efficiency measurement of production processes. On the other hand the final product in the service companies is a realized service that is by its nature transient, intangible and quantity immeasurable, for which realization is often necessary to employ different measurable resources such as space, time, labor, etc.

Products of logistics companies, as well as the typical service companies are: transport services, warehouse services, material-handling services, freight forwarding services and other services. For their realization it is necessary to use various resources such as transport and material handling equipment, warehouse space, time, energy, labor, etc. whose usage is not easy measurable. An additional problem of measuring efficiency in logistics is the complexity, integration and mutual dependence of both resources involved, and realized services. When defining performances of logistics systems, it is possible to make very different and even conflicting aspects of performances. Defining and measuring the efficiency of logistics systems, as one of the most important performances in recent years is very significant. The existing models for measuring and monitoring efficiency are not fully applicable in the logistics and contain numerous constraints. The lack of models for measuring and monitoring the efficiency in logistics systems applicable in practice is evident. This confirms the lack of papers and models tested on the real examples. The aforementioned problem and the importance of monitoring and measuring the efficiency of logistics services for practitioners and researchers are main motive of this paper. This paper provides an overview of problems for measuring the efficiency in logistics. The paper also gives opportunities for overcoming mentioned problems.

2. THE MAIN PROBLEMS

Measuring the efficiency of logistics systems and processes follows several groups of problems (Figure 1):

- Indicator selection;
- Efficiency measurement levels;
- Efficiency decomposition;
- Conflicting goals;
- Shared resources;
- Measuring efficiency of supply chains;

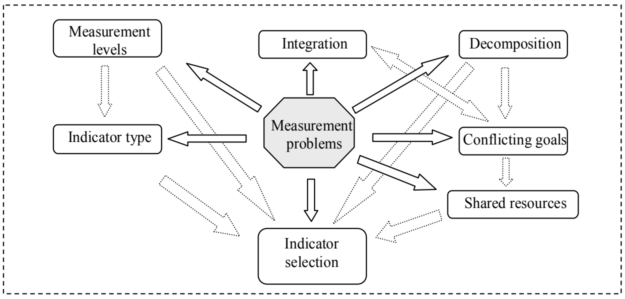

Figure 1. Efficiency measurement problems

Mentioned problems are the main problems in the efficiency measurement process of logistics systems. However, there are many additional problems that can not be predicted in the model development process.

2.2 Problem of measuring efficiency in the presence of multiple indicators

Logistics systems operating describe a large number of different indicators, and the problem is how to select relevant indicators which describe DC operating in the best way. The variables selection problem is recognized in literature [4]. Various indicators (operational, environmental, energy, qualitative, socio-economic, etc.) expressed in different units, related to different decision making levels (strategic, tactical, operational level) further complicate the indicator selection.

Under these conditions, the selection of indicators is problematic and critical process. In the real systems numerous indicators are monitored. Mentioned "single ratio" indicators give partial picture of logistics systems operating.

2.3 Efficiency decomposition problem

Efficiency decomposition is very important for logistics systems. In certain situation it is necessary to measure the efficiency of logistics subsystem, process and activity, not just system as whole. There is a lack of papers in literature that analyse this problem. The problem of shared resources and conflicting goals between logistics subsystems, processes and activities complicates efficiency decomposition [10]. The main task of the logistics system in terms of efficiency can be formulated as maximizing the overall efficiency of the logistics system and its subsystems, under conditions of shared resources and conflicting goals (Figure 2). However, each subsystem within the logistics system has its own strategy to achieve efficiency. The efficiency of one subsystem may be the result of the inefficiency of the other subsystem.

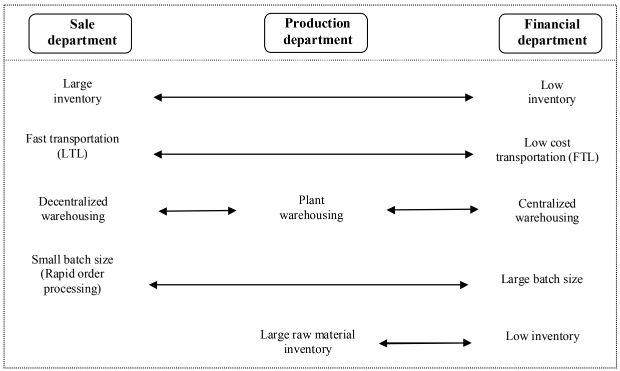

Figure 2. Conflicting goals of different sectors [10]

2.4 Problem of measuring supply chain efficiency

This problem relates to integration and influence of all participants in the supply chain. Each member in the supply chain is an independent actor with its own strategy to achieve efficiency. In general, the structure of the supply chain can be represented as in Figure 3. Some measures are associated with a specific supply chain member only. These measures are called the "direct" inputs and outputs. There are also "intermediate" inputs/outputs that link two members in the supply chain. For one member these measures represent inputs, while for another represent outputs.

Supply chain management requires the performance of overall supply chain rather than only the performance of the individual supply chain members. Sometimes, because of the possible conflicts between supply chain members, one member's inefficiency may be caused by another's efficient operations. For example, the supplier may increase its raw material price to increase its revenue and to achieve an efficient performance. This increased revenue means increased cost to the manufacturer. Consequently, the manufacturer may become inefficient unless the manufacturer adjusts it current operating policy.

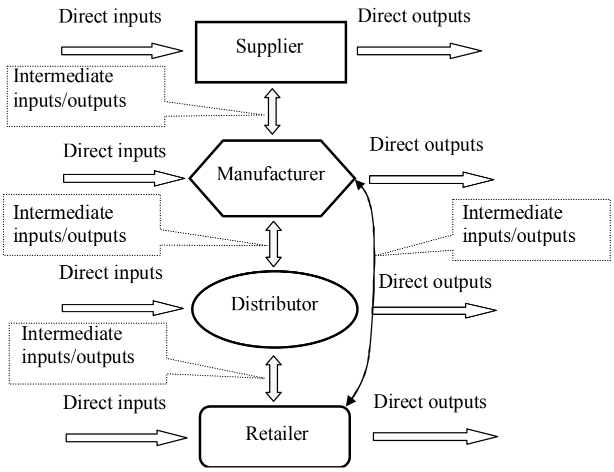

Figure 3. Supply chain structure

The integration of all supply chain members in the supply chain process represents particular problem. In addition to suppliers, manufacturers, distributors and users sometimes appear supplier of suppliers, customer of customers, distributor of distributors, etc. There are also companies that are members of several supply chains (for example, glass manufacturer can supply chain member of several car manufacturers). For this reason, some authors advocate for measuring the efficiency of individual companies in the supply chain, which is essentially a simpler case.

3. EFFICIENCY OF LOGISTICS PROCESSES IS NOT MEASURED IN THE RIGHT WAY

Measuring the efficiency is very important and difficult issue for each company. This problem is present both in the literature and in the practice, regardless of the type and size of the company. According conducted research about measuring and monitoring efficiency in the real systems certain conclusions are made. In the distribution centres and the other logistics systems only “single ratio” indicators are monitored. The indicators like distance/driver, order picking transaction/order picker, warehouse and vehicle space utilization, etc. are known as partial productivity indicators and do not provide enough information about the company's operation. Many of them are included in others, which to some extent can lead to confusion.

The financial indicators are the most important for the logistics managers. In that manner the great attention is paid to costs (fixed and variable), profit and turnover. The indicators are always observed independently without establishing the relationship with other indicators and parameters. Beside financial indicators operational (distance, shipped pallets, number of deliveries) and utilisation indicators (warehouse and vehicle space utilization, vehicle time utilisation) are also monitored. The efficiency is identified as the partial productivity. In that manner efficiency of vehicle is defined as relation between distance driven and fuel consumption, while order picker efficiency is relation between number of order picker transactions per day. The mentioned indicators do not provide real picture about vehicle efficiency or order picker efficiency, because do not take into account all the parameters. It is also not good to make decisions based on mentioned parameters. For calculation mentioned efficiency indicators and single ratio indicators, simple mathematical operations of multiplication and division are used. On the basis of the above findings, the review of reports and interviews with managers and other employees it may be concluded that the efficiency is not monitored or is not monitored on the right way.

On the other hand, the situation in the literature is not much better. The most of the models proposed in the literature can not be applied on the real logistics systems. The almost all models are based on the DEA (*Data Envelopment Analysis*) method. This method has several disadvantages and it is not applicable in all situations. Among others, the discriminatory power of the DEA method decreases when the number of indicators increases. Models in literature are theoretically developed, and often inapplicable on real problems. This paper shows how to overcome mentioned problems on real case studies.

4. MEASURING EFFICIENCY OF DISTRIBUTION CENTRES IN THE PRISENCE OF NUMEROUS INDICATORS

The problem of measuring the efficiency of logistics systems in the presence of numerous indicators is recognized in literature. All approaches in literature solve this problem selecting several representative indicators. The selection process is realized according decision maker opinion. However, in this way valuable information may be lost. In [2] authors propose new approach for measuring the efficiency of the logistics systems in the presence of the numerous indicators. Unlike other approaches where the variables are selected, this approach from a large number of indicators makes several artificial variables with a minimal loss of information. The variables from the first stage are than used for efficiency evaluation. The proposed approach also gives opportunities for investigation the influence of all indicators in efficiency scores.

4.1 Problem of measuring DCs efficiency

The authors analyze the efficiency of the seven distribution centres in Serbia. Data has been aggregated for the twelve months of 2011. Each DC in each month is a separate decision making unit. Thus, a set of 84 DMUs is observed. The company management has used a variety of the "single ratio" indicators to monitor the operating of the DCs. As mentioned before this indicators do not provide enough information about the company's operation. According to various criteria, the indicators in logistics can be classified in different ways. In the observed case authors classify indicators into five groups as shown in Table 1. Input and output category is indicated in the third column. The warehouse and transport indicators are marked in the fourth column. Equipment and capacity indicators include general indicators frequently used in literature [7]. The largest group is the operational indicators group. Similar indicators are used in the literature ([3]; [9]). There are also "single ratio" indicators that observed DCs monitor, and to the best of authors' knowledge have not been used in the literature. Drivers overtime per driver and order picking transactions per order picker are some of them. Energy indicators are very important for logistics systems. Energy consumption costs in the DCs have a great share of total costs. Utilization factors greatly influence the operating of the company, on total costs, as well as on efficiency [11]. Apart from the warehouse and vehicle space utilization this paper also analyses time utilization of truck in the distribution process.

Failures in the transport and warehouse subsystems represent quality indicators which may be the cause of dissatisfaction and complaints of the customer. According [2] failures in the warehouse relates to the mistakes in the order picking process (shortage/excess in the delivery, articles mix-up, damages), but also to other processes such as bad inventory management, etc. Failures in the transport primarily concern the delivery that is falling behind schedule, as well as the damaging and losing goods in the transport process.

Table 1. Indicators for DC's efficiency measuring

Type	*Variables*	*I/O*[a]	*W/T*[b]
Equipment and capacity indicators	Vehicles	I	T
	Forklifts	I	W
	Employees in warehouse	I	W
	Employees in transport	I	T
	Warehouse area	I	W
	Pallet places	I	W
Energy	Fuel	I	T
	Electricity consumption	I	W
	Other energy costs (water, gas)	I	W
	Utility costs	I	W
Operational	Invoices (Demands)	I	W-T
	Warehouse overtime	I	W
	Driver's overtime	I	T
	Vehicle maintenance	I	T
	Driver's overtime/driver	I	T
	Shipped pallets	O	T
	Distance	O	T
	Deliveries	O	W-T
	Order picking transactions	O	W
	Tour/driver	O	T
	Delivery/driver	O	T
	Tons/ driver	O	T
	Pallets/driver	O	T
	Distance/driver	O	T
	Order picking trans./order picker	O	W
	Turnover	O	W-T
Utilisation	Time truck utilisation	O	T
	Space truck utilisation	O	T
	Warehouse space utilisation	O	W
Quality	Failures in warehouse	O	W
	Failures in transport	O	T
	Write off expired goods	O	W
	Total failures	O	W-T

[a] I-Input;O-Output; [b] W-Warehouse indicator; T-Transport indicator

4.2 Model definition

The proposed methodology is realized in two phases. In the first phase, it is necessary to implement the PCA for each of the groups of inputs and outputs separately. The PCs from the first stage are used as inputs and outputs in the second phase. PCA-DEA models are used in the second phase for efficiency evaluation. The model has the following form:

$$\min_{U_{PC},V_{PC}} V_{PC}X_{PC}^{a} - v^{a} \tag{1}$$

$$V_{PC}X_{PC} - U_{PC}Y_{PC} - v^{a} \geq 0 \tag{2}$$

$$U_{PC}Y_{PC}^{a} = 1 \tag{3}$$

$$V_{PC_1^{equipm}} - V_{PC_2^{equipm}} \geq 0 \tag{4}$$

$$V_{PC_3^{energy}} - V_{PC_4^{energy}} \geq 0 \tag{5}$$

$$V_{PC_5^{operat}} - V_{PC_6^{operat}} \geq 0 \tag{6}$$

$$V_{PC_6^{operat}} - V_{PC_7^{operat}} \geq 0 \qquad (7)$$

$$U_{PC_1^{utilisat}} - U_{PC_2^{utilisat}} \geq 0 \qquad (8)$$

$$U_{PC_3^{quality}} - U_{PC_4^{quality}} \geq 0 \qquad (9)$$

$$U_{PC_4^{quality}} - U_{PC_1^{utilisat}} \geq 0 \qquad (10)$$

$$U_{PC_4^{quality}} - U_{PC_5^{operat}} \geq 0 \qquad (11)$$

$$U_{PC_4^{quality}} - U_{PC_1^{utilisat}} \geq 0 \qquad (12)$$

$$U_{PC_4^{quality}} - U_{PC_5^{operat}} \geq 0 \qquad (13)$$

$$V_{PC} \geq 0 \;\; U_{PC} \geq 0, \;\; v^a \; free \qquad (14)$$

In the previous model $V_{PC_1^{equipm}}$ and $V_{PC_2^{equipm}}$ represent weights assign to the the PCs from the group of equipment and capacity inputs, $V_{PC_3^{energy}}$ and $V_{PC_4^{energy}}$ the PCs from energy inputs group, $V_{PC_5^{operat}}$ and $V_{PC_6^{operat}}$ from the operational inputs group. Similar, $U_{PC_1^{utilisat}}$ and $U_{PC_2^{utilisat}}$ are weights assigned to the PCs of utilisation indicators group, $U_{PC_3^{quality}}$ and $U_{PC_4^{quality}}$ the PCs from quality output group, $U_{PC_5^{operat}}$ and $U_{PC_6^{operat}}$ the PCs from operational output group.

4.3 Case study results

The first phase of the efficiency measuring is the PCA for all groups of inputs and outputs separately. From each of six groups main components were selected. All extracted components explain minimum 80% of total variance of each group (Table 2). Two PCs are extracted from equipment and capacity input indicators. They explain a vast of the majority of the variance in the original data matrices, since they explain more than 90%.

From the group of energy indicators two PCs are also extracted. In the first PC which explains 55% of total variance electricity and fuel consumption has the greatest influence, while in the second PC other energy costs have the greatest influence. Three operational input PCs explain 87% of variance.

On the output side six PCs are extracted. The first relates to utilisation factors in transport (time and space truck utilisation), while the second relates to warehouse space utilisation. In the quality output group two PCs are dominant. The first quality output PC incorporates failures in the warehouse and transport, as well as total failures, while the second incorporates write off expired goods. In the last output group two PCs are extracted. The shipped pallets, distance driven and turnover are largely correlated with the first PC. The warehouse indicators (order picking transactions and order picking transactions/order picker) are dominant in the second PCs of mention group.

Table 2. PCA scores (Correlation between variables and PCs)

Inputs	Average	St. dev.	*PC 1*	*PC 2*	*PC 3*
Vehicles (No)	22.38	8.11	0.901	-0.390	
Forklifts (No)	51.76	25.18	0.950	0.047	
Employees in warehouse (No)	71.35	31.84	0.859	-0.468	
Employees in transport (No)	46.51	21.74	0.984	-0.070	
Warehouse area (m^2)	8173.62	3311.03	0.737	0.501	
Pallet places (No)	4484.86	1947.72	0.699	0.584	
Variance explained			*74.19%*	*90.34%*	
Fuel (10^3 m.u.)	2528.43	1673.49	0.849	-0.026	
Electricity consumption (10^3 m.u.)	481.89	281.53	0.945	0.061	
Utility costs (10^3 m.u.)	125.36	249.10	0.689	-0.487	
Other energy costs (water, gas, etc) (10^3 m.u.)	167.76	157.78	0.335	0.897	
Variance explained			*55.02%*	*81.17%*	
Invoices (Demands) (10^3)	8505.01	2896.76	0.833	-0.355	0.142
Warehouse overtime (h)	373.33	445.21	0.375	-0.660	-0.630
Driver's overtime (h)	450.20	242.33	0.683	0.524	-0.282
Vehicle maintenance (10^3 m.u.)	649.08	431.42	0.747	-0.290	0.508
Driver's overtime/driver (h/driver)	13.82	8.49	0.627	0.641	-0.110
Variance explained			*45.05%*	*71.67%*	*87.02 %*
Outputs					
Time truck utilisation (%)	34.38	7.32	0.919	-0.020	
Space truck utilisation (%)	66.77	15.60	0.847	-0.389	
Warehouse space utilisation (%)	89.68	13.06	0.381	0.913	
Variance explained			*56.86%*	*89.71%*	
Failures in warehouse (10^3 m.u.)	48.51	46.80	0.836	-0.336	
Failures in transport (10^3 m.u.)	174.74	250.89	0.829	-0.185	
Write off expired goods (10^3 m.u.)	45.85	68.91	0.601	0.794	
Total failures (10^3 m.u.)	480.17	894.63	0.969	-0.045	
Variance explained			*67.16%*	*86.67%*	
Shipped pallets (No)	9021.48	4534.55	0.992	-0.088	
Distance (10^3 km)	116.01	68.03	0.954	-0.188	
Deliveries (No)	4270.15	1751.67	0.759	0.435	
Order picking transactions (10^3)	188.29	98.94	-0.042	0.913	
Turnover (10^6 m.u.)	281.06	178.81	0.955	0.023	
Tour/driver (No/driver)	27.36	13.64	0.909	-0.084	
Delivery/driver (No/driver)	112.52	28.06	0.764	0.314	
Tons/ driver (t/driver)	96.94	60.43	0.982	-0.092	
Pallets/driver	214.80	107.97	0.992	-0.088	
Distance/driver (km/driver)	2762.20	1619.86	0.954	-0.188	
Order picking trans./order picker (No/order picker)	6737.95	999.54	0.166	0.888	
Variance explained			*69.83%*	*88.14%*	

The second phase of efficiency measurement process is the PCA-DEA model for evaluating efficiency. The classical DEA models can not be applied in this case. They do not have sufficient discriminatory power, considering the fact that almost 99% of DMUs are efficient.

There are numerous quality indicators in logistics. The ultimate goal, however, is customer satisfaction. No matter what indicator is concerned the quality of service greatly affects customer satisfaction. Satisfied and loyal customers mean a secure income for the company. On the other side unsatisfied customers and customer's complaints create additional costs. In this paper, more attention is paid to the failures in the distribution process. The author's assumption that quality indicators are more relevant for the efficiency evaluation is confirmed. This model maximizes discrimination with minimal loss of information. In that manner the PCA-DEA approach is more appropriate for the efficiency evaluation. The porposed model make greater differentiation between DMUs. Only 21% of the all DMUs are efficient with the average efficiency score 0.82.

5. CONCLUSIONS

Measuring the efficiency in logistics follows number of problems. Problems are present both in the literature and in the practice. In literature, there is a lack of case studies that test the efficiency measurement models on real logistics systems. This fact indicates the insufficient amount of research in this area. This paper shows how to overcome efficiency measurement problems, and how theoretical model can be applied in practice. The model proposed in this paper corresponds to a real situation of the observed logistics systems. The model also combined information obtained from employees and approaches from literature. The proposed methodology represents support in the decision making process. The model proposed in this paper, with minor adjustments, can be used for measuring and improving the efficiency of providers, warehouses, suppliers, etc. The presented models are a good basis for development of the future models. In the future research, models should include environmental and other quality indicators.

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