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DRAFT TO IMPLEMENT A LOGISTICS INFORMATION SYSTEM FOR CORPORATE MANAGEMENT USING MULTI-CRITERIA DECISION MAKING METHODS

Abstract

This manuscript is focused on describing and analyzing certain logistics processes and activities in a chosen light manufacture, warehouse and distribution enterprise, and subsequently a proposal for implementing a suitable logistics information system for corporate management providing interconnection among all the logistics activities of such an enterprise. The first two chapters outline the basic concepts related to the issue of logistics processes, electronic information systems as well as a brief description of the analyzed enterprise. The following chapters consist of the most important parts of this research study. An advanced logistics information system is specified and thereafter implemented on the basis of a predefined set of criteria and by implementing certain opted methods included into the Operations Research, particularly the multi-criteria decision making problems. Specifically, the Scoring Method is utilized, and subsequently the results obtained are compared using the Saaty quantitative pairwise comparison method.

Keywords: corporate management, logistics information system, multi-criteria decision making, Scoring method, Saaty quantitative pairwise comparison method

JEL: M15, L63, L86, L96

Introduction

Nowadays, virtually no field of business can work and develop its activities without a proper information system. Apparently, a transport or logistics enterprise is no exception, due to the fact that accurate information and sufficient data should be transmitted in a timely manner for successful operation of all logistics processes.

Thus, it can be stated that logistics is one of the fields where the information flow is based on the material and financial flow (Bazhenov et al., 2019). Not such a long time ago information was exchanged and kept in the paper form. Compared to this, automated and electronic information flows are much faster, more accurate, and allow much more information to be transmitted and transferred at once (Krásenský, 2010; Grischuk, Gunicheva, 2017).

Electronic logistics information systems enable the collection, processing, analysis, distribution, retention and evaluation of data necessary to ensure the continuity of functional logistics processes. Generally, a logistics information system (hereinafter referred to as LIS) is defined as interconnected hardware and software systems designed to support the logistics components; e.g., coordination of logistics activities, material flow, and inventory replenishment; i.e. a subset of an organization's entire information system, and is focused on the particular issues associated with logistics decision making (Odero et al., 2017; Liu, Lin, 2019).

To put it simply, an LIS may cover all fields of the following logistics activities and is made up of individual information systems/components (see Figure 1):
- Material Codification;
- Asset Management;
- Value-added Logistics Services;
- Organization Management;
- Personnel Management;
- Warehouse Management;
- Supply Management;
- Distribution Management;
- Handling and Transport Equipment Operation and Maintenance;
- Transportation Management;
- Consignment Tracking;
- Facilities Management;
- Acquisition Management;
- Surplus Management;
- Material Resources Management;
- Logistics Support for Operations;
- Crisis Management Support;
- Standardization Management (Sýkorová, Čverhová, 2011; Lorenc et al., 2016; Eschenfelder et al., 2019).

The information systems that belong to the LIS have a modular structure, having at the same time a variety of techniques that allow evaluation of data. Such a type of structure allows individual information systems to retain their special features, as well.

The LIS allows not only evaluating the actual data, but also creating the planning data. The information systems provide easy-to-use planning functions which are also supported by a forecasting function. The planning functionality of the information systems and the component sales and operations planning have been combined and enhanced to make one central planning and forecasting tool/component.

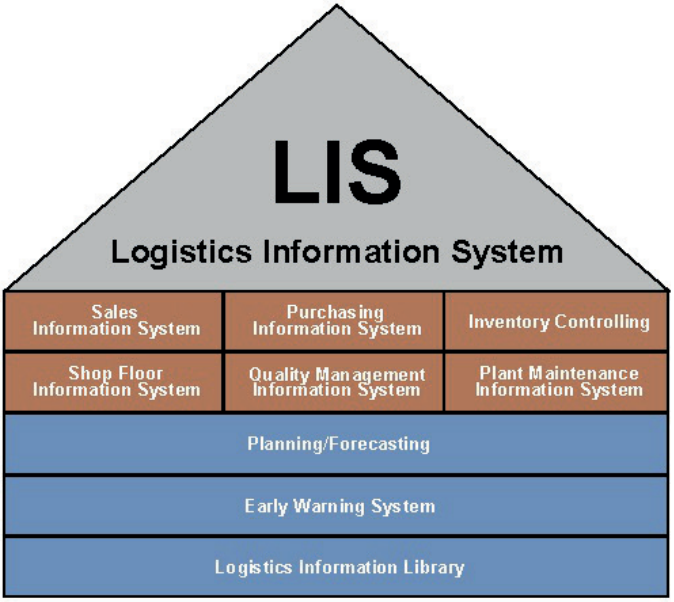

Figure 1. An overview of individual components of a Logistics Information System
Source: (own elaboration based on: Eschenfelder et al., 2019)

The Early Warning System is integrated in all of the information systems and is based on the key figures of the information system. The Early Warning System supports the decision making process by allowing the customer to target and monitor weak areas in logistics. It searches for exceptional situations and helps in the early detection and correction of undesirable situations.

The Logistics Information Library is a further component of the specific LIS. The Logistics Information Library makes it possible to access key figures in the LIS by using simple search strategies. In addition, the Logistics Information Library allows cataloging the key figures.

With the constant need to meet the ever-increasing customer demands and needs, the LISs are being advanced, more sophisticated and optimized, as well as interconnected among suppliers, transport operators, logistics providers and customers (Rasouli, 2019; Lizbetin, 2018; Mahmoudsalehi et al., 2019).

Hence, following the outlined topic within the introduction chapter, the research problem and the main objective of the manuscript may be formulated. It lies in designing an approach methodology in terms of searching for an appropriate logistics information system for corporate management of a particular enterprise when applying the specific multi-criteria decision making methods (in particular, the Scoring Method and the Saaty quantitative pairwise comparison method).

1. Description of the examined enterprise

In cooperation with the chosen enterprise, Alpha, a suitable corporate management logistics information system may be implemented based on the corporate requirements. Since it represents a relatively small enterprise with assembly, warehouse and distribution operations as well as assistance services including immobile or damaged vehicle towing, removing obstacles in connection with road transport, and displacement of heavy or oversized loads; i.e. it may be referred to as a complex 3PL (Third Party Logistics) provider, however, not able to develop its own software, it has decided to purchase a comprehensive advanced logistics information system. This enterprise Alpha is a contractual partner of the Road and Motorway Directorate for interventions on the South Bohemian motorway D3 and has been contracted exclusivity to remove road obstacles in the South Bohemian Region (Ližbetinová et al., 2019; Singh et al., 2018).

With the continuous growth and development of the enterprise and the expansion of the employee base, there are also higher demands on the accuracy of information and the speed of its transmission (transfer). Recently, the enterprise manager (and the owner at the same time) was able to provide most of the corporate logistics processes in-house (on his own), however, nowadays, these processes are divided among several corporate departments. Thus, the need to have an overview, such as the order status, the movement of all vehicles and their crews and the subsequent invoicing regarding the financial indicators, has arisen (Kubasakova et al., 2015). The corporate manager is also aware of the need for the customer relationship management (CRM) which cannot be done without an accurate customer database with an overview of orders.

2. Data and research methods

Based on the enterprise's requirements, specific relevant criteria were identified in terms of implementing the corporate management logistics information system, which must interconnect all the key activities and processes, as well as the information system itself. By linking all the data, the LIS must provide the owner and other competent persons with comprehensive relevant techno-economic information.

2.1. Overview of individual criteria and variants

On the basis of aforementioned, the examined enterprise management determined the basic set of criteria as follows:
- an option to export invoicing data and materials;
- recording vehicle activities and operations;
- working with a larger number of contract partner price lists;
- archiving photographic documentation for a specific order;
- system openness to all corporate departments;
- vehicle tracking by a GPS locator and storing the history;

– an option to interconnect the system with a mobile application.

Due to the abovementioned identified parameters (criteria), four relevant companies dealing with the development of information systems were taken into consideration from the point of view of the decision making process (Chovancova, Klapita, 2017).

In the case of this research study, those companies are named LIS-A, LIS-B, LIS-C and LIS-D. All those companies are focused, *inter alia*, on the development of information systems, and precisely, the management logistics information system interconnecting corporate economic activities with transport (logistics) and it is the customer part that matters for the enterprise.

2.2. Multi-criteria decision making

Individual methods and techniques of multi-criteria decision making issues (including methods of determination of the criteria weights as well as methods of multi-criteria evaluation of alternatives) differ, *inter alia*, in whether they give ordinal or cardinal information about the ranking of individual variants (or the importance/preference of individual criteria) and whether they need ordinal or cardinal information about individual variants by each criterion (Golini et al., 2018; Mirkouei et al., 2017).

First of all, the Scoring Method is applied for the purpose of the evaluation procedures of this research study. As a result, this method gives cardinal information about the preferences of individual criteria (Rezaei et al., 2018). The criteria and their weights were determined in cooperation with the investigated enterprise management, the enterprise's clients as well as based on the opinion of several external experts in the particular issues. They evaluated the individual criteria and rated them by points in the range of 1–5 (see Table 1).

Thus, a rating scale of variants depending on each determined criterion was drawn up as shown in Table 1.

Table 1. Rating scale of variants by each criterion

Numerical evaluation	Corresponding assessment
1	Not allowing, not included
2	Allowing with difficulty, or the implementation is unsatisfactory
3	Allowing with problems, features are not ideal
4	Allowing a function with less reservations
5	Allowing, absolutely satisfactory

Source: (own elaboration)

Based on the following procedure, a criterion matrix (Nadoushani et al., 2017) may be compiled (see Table 2). The method procedure consists in several follow-up steps:

– each variant is evaluated by the determined criteria – *sij*;
– for the quantification of information by the each criterion, a scale of 1–5 is used so that the best rating is 5;

– the total evaluation of each variant is then calculated as the sum of the partial values (see Equation 1):

$$s_i = \sum_{j=1}^{k} s_{ij}, \quad i, j = 1, 2, \dots, \mathrm{k}, \tag{1}$$

where:
s_i is the total score of variants (variant preference index);
s_{ij} are the elements of the criterion matrix;

– subsequently, all the variants are ranked in a descending order by *si* and the best (compromise) option can be determined.

If multiple options are demanded, the required number of variants with the highest *si* values is selected. The procedure may also be extended by the weighting criteria, the *si* values are then calculated as normalized sums (Maznah et al., 2011; Hwang, Yoon, 1981).

As for the second technique, the Saaty method is applied. This is a method of a quantitative pairwise comparison of individual criteria. Generally, for the evaluation of paired comparison of criteria, a 9 point scale is utilized. For more detailed evaluation of criteria pairs, it is possible to use intermediate values as well (2, 4, 6, 8) (Lin, 2019; Hu, Sheng, 2014; Saaty, 2013):
1 – equal criteria *i* and *j*;
3 – slightly preferred criterion *i* above *j*;
5 – strongly preferred criterion *i* above *j*;
7 – very strongly preferred criterion *i* above *j*;
9 – absolutely preferred criterion *i* above *j*.

The evaluation process using the Saaty method (Saaty, 2013) is based on the fact that the researcher (expert / decision maker) compares each pair of criteria and inputs the value of preferences of *i*-th in relation to the *j*-th criterion into the Saaty matrix $S = (s_{ij}, i,j = 1, 2, \dots, k)$. In case that the *j*-th criterion is preferred above the *i*-th criterion, inverse values are entered into the Saaty matrix ($s_{ij} = 1/3$ for low preference, $s_{ij} = 1/5$ for strong preference, etc.) (Hu, Sheng, 2014).

In the Saaty matrix, $s_{ji} = {}^{1}/_{s_{ij}}$, and furthermore ($s_{ij} \approx {}^{v_i}/_{v_j}$ represents the approximate ratio of the criterion weight *i* and *j*).

This already indicates the basic characteristics of the Saaty matrix. Saaty (2013) designed several numerically very simple ways by which individual weights *vi* can be estimated. The vectors of their values are denoted as $v_i = (v_1, v_2, \dots, v_k)$. The most common method to be applied to calculate the weights is referred to as a normalized geometric mean of a line in a Saaty matrix. The Saaty method can be used not only to determine the preferences between the criteria, but also among individual variants by analyzing the original assignment, which is called an Analytic Hierarchy Process (hereinafter referred to as the AHP method) (Hruška et al., 2014).

To calculate the geometric mean of each row of matrix *S* (Equation 2) (Hruška et al., 2014):

$$g_i = \sqrt[k]{\prod_{j=1}^{k} s_{ij}}, \dots i, j = 1, 2, \dots, k, \tag{2}$$

where:
g_i is the geometric mean;
s_{ij} are elements of the Saaty matrix;

∏ is the product of the values of the Saaty matrix elements.

Normalization of the geometric mean (Equation 3) (Hruška et al., 2014):

$$v_i = \frac{g_i}{\sum_{i=1}^{k} g_i}, \ldots i, j = 1, 2, \ldots, k, \tag{3}$$

where:
v_i is the normalized geometric mean;
g_i is the geometric mean;
∑ is the sum of geometric mean values.

3. Obtained results

In regard to the Scoring Method, to obtain the desired results, a criterion matrix for individual logistics information systems needs to be compiled based on the evaluation values by each criterion using a rating scale and a decision matrix. Then, the sum of the individual variant values by each criterion according to Equation 1 and the resulting order of individual logistics systems can be determined. The resulting evaluation of variants is summarized in Table 2.

Table 2. Criterion matrix and the resulting evaluation of variants by the Scoring Method

Criterion	Variant			
	LIS-A	LIS-B	LIS-C	LIS-D
C_1 – export of invoicing data and materials	4	5	3	5
C_2 – recording vehicle activities and operations	5	5	5	5
C_3 – working with a larger number of contract partner price lists	2	3	1	4
C_4 – archiving photo-documentation for a particular order	1	1	1	3
C_5 – system openness to all corporate departments	5	5	5	4
C_6 – vehicle tracking by GPS locator and storing the history	3	4	4	4
C_7 – interconnecting the system with a mobile application	1	5	1	5
The resulting ∑ values	21	28	20	31
Weighted mean = result values ∑ / number of criteria	3	4	2.857	4.286
Variant rankings	3	2	4	1

Source: (own elaboration)

As for the Saaty method, the obtained criteria pair values (assigned by the corporate management, the enterprise’s clients as well as based on the opinion of several external experts) were used to calculate the weights of individual LIS parameters (see Table 3). The sum of all the weight values must be equal to 1.

Table 3. The resulting Saaty matrix

Criterion	C_1	C_2	C_3	C_4	C_5	C_6	C_7	g_i	v_i
C_1	1	1/5	3	5	1	1/3	1	1.000	0.101
C_2	5	1	7	9	3	1	1	2.661	0.269
C_3	1/3	1/7	1	3	1	1/7	1/5	0.456	0.046
C_4	1/5	1/9	1/3	1	1/3	1/9	1/7	0.235	0.024
C_5	1	1/3	1	3	1	1/5	1/5	0.631	0.064
C_6	3	1	7	9	5	1	3	3.113	0.315
C_7	1	1	5	7	5	1/3	1	1.788	0.181
								$\sum = 9.884$	$\sum = 1.000$

Source: (own elaboration)

Assigning the judgment of decision makers (experts, clients and corporate management) to each of the criteria represents the first step of the AHP method. Subsequently, according to the general AHP procedure, a comparison of individual variants by individual criteria needs to be performed (Hruška et al., 2014; Triantaphyllou, Mann, 1995).

And again, experts, enterprise clients and corporate management were asked to specify preferences among individual variants by each criterion. Each of the experts set a level of significance for each pair of the LIS by the corresponding criterion (Jurkovi , Sosedová, 2013). And a product of the sub-matrices of all decision-makers was established for each matrix evaluation element (Podvezko, 2009), and subsequently the mean was calculated.

All comparisons of the LIS by each criterion are summarized in the following tables (Tables 4–10).

Table 4. A comparison matrix of the variants by C_1

C_1	LIS-A	LIS-B	LIS-C	LIS-D
LIS-A	1	1/3	3	1/3
LIS-B	3	1	5	1
LIS-C	1/3	1/5	1	1/5
LIS-D	3	1	5	1
v_i	0.151	0.391	0.067	0.391

Source: (own elaboration)

Table 5. A comparison matrix of the variants by C_2

C_2	LIS-A	LIS-B	LIS-C	LIS-D
LIS-A	1	1	1	1
LIS-B	1	1	1	1
LIS-C	1	1	1	1
LIS-D	1	1	1	1
v_i	0.250	0.250	0.250	0.250

Source: (own elaboration)

Table 6. A comparison matrix of the variants by C_3

C_3	LIS-A	LIS-B	LIS-C	LIS-D
LIS-A	1	1/3	3	1/5
LIS-B	3	1	5	1/3
LIS-C	1/3	1/5	1	1/7
LIS-D	5	3	7	1
v_i	0.118	0.263	0.055	0.564

Source: (own elaboration)

Table 7. A comparison matrix of the variants by C_4

C_4	LIS-A	LIS-B	LIS-C	LIS-D
LIS-A	1	1	1	1/5
LIS-B	1	1	1	1/5
LIS-C	1	1	1	1/5
LIS-D	5	5	5	1
v_i	0.125	0.125	0.125	0.625

Source: (own elaboration)

Table 8. A comparison matrix of the variants by C_5

C_5	LIS-A	LIS-B	LIS-C	LIS-D
LIS-A	1	1	1	3
LIS-B	1	1	1	3
LIS-C	1	1	1	3
LIS-D	1/3	1/3	1/3	1
v_i	0.300	0.300	0.300	0.100

Source: (own elaboration)

Table 9. A comparison matrix of the variants by C_6

C_6	LIS-A	LIS-B	LIS-C	LIS-D
LIS-A	1	1/3	1/3	1/3
LIS-B	3	1	1	1
LIS-C	3	1	1	1
LIS-D	3	1	1	1
v_i	0.100	0.300	0.300	0.300

Source: (own elaboration)

Table 10. A comparison matrix of the variants by C_7

C_7	LIS-A	LIS-B	LIS-C	LIS-D
LIS-A	1	1/9	1	1/9
LIS-B	9	1	9	1
LIS-C	1	1/9	1	1/9
LIS-D	9	1	9	1
v_i	0.050	0.450	0.050	0.450

Source: (own elaboration)

In total, seven criteria were specified, and the weight was calculated for each of them. This weight must be subdivided among the variants. The weights of each criterion as well as the variant depending on these criteria were calculated (see Tables 4–10). The total values of each variant by individual criteria multiplied by the weight of the corresponding criterion had to be counted to determine the overall variant rankings. Subsequently, the variants were sorted in the descending order whereby the final variant's ranking (i.e. final evaluation of variants) was defined (see Table 11).

Table 11. The resulting evaluation of the variants by the Saaty method

Variant	Criterion							Total values	Variant rankings
	1	2	3	4	5	6	7		
LIS-A	0.151	0.250	0.118	0.125	0.300	0.100	0.050	0.1507	4
LIS-B	0.391	0.250	0.263	0.125	0.300	0.300	0.450	0.3170	2
LIS-C	0.067	0.250	0.055	0.125	0.300	0.300	0.050	0.2023	3
LIS-D	0.391	0.250	0.564	0.625	0.100	0.300	0.450	0.3300	1
Criteria weights	0.101	0.269	0.046	0.024	0.064	0.315	0.181	–	–

Source: (own elaboration)

4. Discussion of the results

The selection of the appropriate method depends on the point of view of the decision maker (investigator) interested in the given subject. Proposing a suitable logistics information system for corporate management can be viewed as a decision making problem in which the final decision is influenced by a group of external factors. For the purpose of addressing MCDM problems, the methods of multi-criteria analysis are used which therefore can be used even while deciding about the appropriate LIS selection. There are many different methods of multi-criteria decision analysis which can help in such an issue. Nevertheless, in practice, many of these methods cannot be applied as they do not allow processing all the intricacies intended in this manuscript. Another significant problem field for the application of certain methods consists in the fact that we do not know the details of LIS customers and users, which we could have analyzed.

The final decision summarized in Table 2 (applying the Scoring Method) shows that the best possible value within the ranking is achieved by the LIS-D system, the LIS-B system is ranked second in the row, the third place is assigned to the LIS-A system and the LIS-C system scores the least points, thus taking the last place in the ranking.

On the other hand, when using the Saaty quantitative pairwise comparison method (or the Analytic Hierarchy Process method), although the greatest calculated value is obtained by the LIS-D system as well, which is thus ranked first, and also the LIS-B variant is ranked second, nevertheless, the third place is assigned to the LIS-C variant and the LIS-A system scores the least points, and thus for a change, it is ranked on the last position. Either way, if the enterprise chooses to procure the LIS-D system, it will obtain an appropriate system to support its processes to ensure all the economic and logistics activities.

Each of the methods implemented appears to be relatively easy to handle and apply to the complex and difficult task of selecting a suitable LIS for corporate management. Furthermore, a number of criteria have a lesser or greater impact on the final decision in this regard. It was necessary to apply such a method that would allow the decision maker to judge the relationship significance (preference) between the two criteria compared. In addition to that, the Saaty method allows a detailed division of these preferences.

Conclusions

Analyses of a variety of logistics processes (in various countries) resulted in the necessity to implement a management logistics information system into enterprises, since currently, still huge amounts of paper work are performed, and information is often transmitted orally or in writing. Therefore, depending on the size, focus and possibilities of enterprises, it is recommended to consider the possibility to create specific software in terms of streamlining various operations and processes, and especially to implement a special tailor-made advanced logistics information system.

Applying the Scoring Method as well as the Saaty quantitative pairwise comparison method, the LIS-D logistics information system for all the assessed criteria achieved excellent evaluations, i.e. almost a full score. In addition, it provides additional interesting feature options, e.g. saving records of call to customers. It is important to emphasize that this represents an information system created directly for enterprise aiding services, and therefore, apparently, it perfectly suits its implementation in the examined enterprise.

The outcomes of this research study have confirmed that both methods for determining the criteria weights represent effective techniques to be applied for purposes of multi-criteria decision making problems in terms of seeking a suitable logistics information system. In addition, the Saaty (AHP) method allows a reduction in the number of the criteria that are taken into account when searching for solutions.

Nonetheless, these are only recommendations according to the above-described methods of calculation, defined criteria and specification of their weights. Furthermore, individual criteria pair preferences differ from one decision maker to another; therefore, the outcome depends on who is making the decision and what their objectives and preferences are. The final decisions and forms of such a methodology will depend on a number of factors and evaluation details by the decision makers concerned.

In the future, in addition to the above, the addressed issue would need to be examined more comprehensively. It is recommended to focus in particular on:

1. Designing a concept of telematics interconnection of on-line information related to multiple logistics activities (their optimal deployment, proper capacity

utilization with respect to material flows, entry prices – fuel, toll, shipping cost, warehousing cost and also with respect to the environment, etc.). By corresponding HW and SW, the basic idea is to support the creation of a platform for the telematics flow of processes inside and outside enterprises. To do this, it is necessary to know the outlook directions for the logistics market development, its participants and customer requirements in terms of the services provided.

2. In terms of the economic advantage/disadvantage of the proposed application of the new LIS, it would be appropriate to address its economic aspect as well. However, due to the complexity of the issue and the limited range of the manuscript, it is not possible to focus on this area. Since there is no universal approach to assess the economic effectiveness of the LIS implementation within enterprises, it also would be reasonable to address this issue as well.

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