Computer Aided Implementation of Logistics Processes – Selected Aspects

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Abstract. The paper presents selected aspects of the application of information technology to support the implementation of logistics processes. The general discussion about optimization logistics processes precedes basics of designing procedure for logistics systems of different scale which are the foundation for three examples of applications tailored for micro-, and mezo-scale logistics systems. Applications are presented and discussed as tools to optimize logistics processes in aspect of their simultaneous usage to create advanced and comprehensive planning tools. Presented tools enable not only the design of selected elements of the logistics system but also allow assessing their effectiveness. An example of the possible use of applications LogMND to support shaping and dimensioning of point and linear logistic network elements and SCHED to support designing warehousing processes are given.

Keywords: Logistics processes · Decision support efficiency · Decision making process

1 Introduction

The business success is related to the implementation of logistics processes like warehousing, transhipments, transport and planning in general. The main objective is to implement logistics processes at the lowest cost, in high quality and efficiently. The role of logistics is of great importance regardless of business, so logistics departments are no longer reserved for large companies only, but also appear in the small companies with several workers. Essential elements of these departments are informatics systems and software tools tailored to the needs. Together with development, expansion and understanding of the logistics processes the set tools evolve and become more flexible, offer a wide range of integrated functionalities and stay an integral parts of logistics systems. The success or failure of business is often decided by a quality of informatics

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system supporting taking rational decisions to increase productivity and effectiveness for both large corporations and small businesses.

One of the most important aspects of modern logistics is the use of multipurpose computer technologies. Special attention is given for supporting designing, control and management of complex logistic systems. The use of appropriate information systems significantly improves the logistics.

The analysis of comprehensive works like [3, 5, 6, 11] or [24] reveals that efficient and proper management of logistics processes of all scales and types is only possible with extensive use of information and telecommunications technology for (a) gathering and processing large amounts of logistics information, and (b)taking rational decisions on the base of those information. Many potential applications of computer science was pointed and discussed [8, 9, 14, 25]. They point basic modelling and optimization issues and name difficulties to be overcome by modern tools.

Selection of the right informatics tool is difficult. This is due to a wide and varied range of software developers, the overlap of functionalities and endless possibilities of configuration and modification. Therefore, it must be preceded by a thorough analysis of the business processes to identify standard elements of the processes to be covered by standard tools, custom items giving a competitive advantage, and the weakest areas to formulate expectations about the functionalities. Implementation of the informatics system should be comprised between constructing completely new solution fully matched to the business and re-adapting business to the system. The choice must be wise, because the tool unsuited to the needs not only improves its performance, but even makes it worse.

Designing logistics system requires solving subsequent logistics tasks in a way ensuring high efficiency and quality of a logistics system in total. To achieve this objective the individual elements of the system should be designed and linked up with a reliable and efficient way already at the stage of designing. The available programming languages and the rapid development of information technology provide great opportunities for dedicated, tailored computer applications suitable to support specific logistics processes.

2 Tools Supporting Decisions in Logistics Processes

Problems investigated in logistics business are in most cases complex multicriteria and multivariate issues attributed to the designing (modelling),management (operation) and controlling stage. Different objective functions can be built for these problems. Generally, the literature (compare [2, 6, 8, 10, 13] and [17, 19–22]) points three main groups of multi-criteria decision support methods:

- methods of multi-attribute utility theory,
- methods based on outranking relation,
- interactive methods, called dialog methods.

The first group is based on the aggregation of different criteria representing different points of view into one utility function to be optimized. After all, few criteria or attributes are reduced to one global parameter through the introduction of appropriate weights. Multi-attribute utility theory assumes that all variants of the problem are comparable. It means that for each pair of variants the decision maker will prefer one or accept them as equivalent.

In the second group of methods, modelling of decision maker preferences is done through outranking relationship, which permits non-comparable variants when decision maker is not able to indicate the better of the two variants. The methods of this group interleave the computational phase and the decision making phase forming a kind of dialogue with the decision-maker. In the first stage decision maker obtains a sample of compromise solutions. In the second, the sample is subjected to the assessment by introducing additional preferential information. Most of these methods are used within a multi-criteria mathematical programming. Dialog methods recently gain popularity. This is due to the fact that the decision maker has greater trust to the final result, thanks to their involvement in the process of solving the problem.

Today's information systems, despite being dedicated to specific areas of the business, embrace a wider area of interest. Integrated information systems consist of interconnected modules representing different groups of functions. Due to the variety of logistics processes throughout the supply chain, the implementation of these processes is supported by different solutions (selected instances) like:

Supplier Relationship Management – for the comprehensive management of purchasing and supply.

Enterprise Resource Planning – for the comprehensive management of purchasing and supply.

Warehouse Management System – for managing warehouse processes.

Customer Relationship Management – including all kinds of business processes related to the broader customer service.

Distribution Resource Planning – for managing distribution networks.

Supply Chain Management – for building a competitive advantage and integrating supply chains.

Transport Management System – for managing transport operations.

Advanced Planning Systems – specialized tools for planning in logistics.

The above-mentioned integrated information systems are used in different areas of logistics business and on different operational levels. These are the examples of typical solutions created on the base of best practices developed by business of different kinds. All businesses have their own requirements and specificities influencing informatics tools. Actually it is not possible to run a logistics business without those tools according to the rule that purchasing and distribution cycle is much shorter that production cycle. It means that some kind of planning is necessary at all levels of supply chain, and also these supply chains must be integrated into a global network for high efficiency, shorter response time, wider offer and lower costs.

Especially the last item – Advanced Planning Systems, is interesting for logistics planning, organization and designing. APS is a type of system tracking costs based on the activities that are responsible for driving costs in the production, distribution or even warehousing. An APS can allocate raw materials and production capacity optimally to balance demand and plant capacity or allocate handling and transport resources to the tasks. Advanced tools are in most cases tailor-made so include specific criteria and objective functions to support detailed processes.

The applications created for specific processes compete with market tools and systems. Own applications have advantage of full coverage of specific business processes and – plausibly – higher efficiency, but usually are not flexible, difficult to modify and need interfaces to other systems. Due to the very different requirements, companies are increasingly looking for computer tools prepared exclusively for their needs and combining features of specialized applications and standard systems based on best practices. Specialized tools for solving decision problems are based on algorithms that allow obtaining a solution in the acceptable time when using appropriate heuristics (like genetic programming) and hybrid algorithms. The following sections will discuss some original tools supporting the logistics process in different aspects.

3 Logistics Systems Designing Procedure

The logistics system is composed of subjects operating in production, supply, distribution and transport area. These elements are engaged according to material flow through superior and subordinated dependences, realizing various activities in order to supply products and services to the final consumer (see [5, 8, 10] or [17]). Logistic systems of different kinds and scales need different tools to be designed and operated, but there are some basic principles forming designing procedure[12].

Logistics system design should be carried out according to defined stages. Each stage should take into account analyse of logistics processes and burden of individual elements of the system, on the required level of detail necessary to identify actual situation, and to propose a cost and technologically effective solution. Full scope of design works of logistic system should contain (Fig. 1):

1. Analysis of the problem;
2. Identification of design data;
3. Formulation of logistics tasks;
4. The configuration (conceptualization) of design variants based on available data;
5. Dimensioning (counting) preferred variants;
6. Simulation of the logistics system operation in selected technological variants;
7. Selection of the best option in terms of specific criteria.

Presented procedure is a general conclusion made in terms of review of handbooks and fundamental publications like [5, 22] or [23]. Each step can be carried out at different levels of detail depending on the progress of the design work. Regardless of the size and complexity of designed (or analysed) logistics system, the first stage is dedicated to formulation of the logistics tasks carried out by the system. This allows getting qualitative and quantitative data about structure of material and information

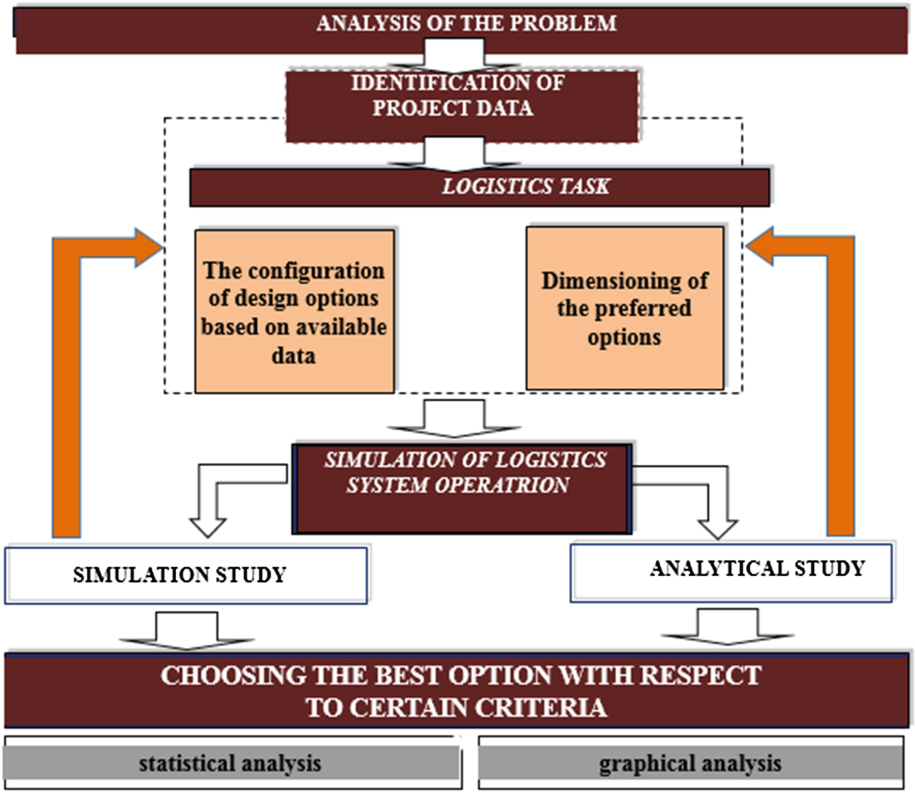

Fig. 1. Diagram of the procedure of logistics systems design [own study]

flows on entrance and on exit from the system and its surroundings. At this stage the evaluation criteria are set to reflect a point of view of decision makers.

The conceptualization means forming processes of material and information flows and selecting proper handling technologies to ensure the implementation of a specific logistics task in a few variants reflecting comparable alternatives. Conceptualized process is dimensioned to reveal necessary work forces, spaces, and time to perform logistics tasks in pursuance of selected evaluation criteria. The last stage is for selecting rational variant on the base of adopted criteria through multi-criteria evaluation.

As already mentioned, there are different areas of implementation that are characteristic for micro-, mezo- and macro logistics. On these three levels different applications can be used for logistics processes optimization. These application will cover more or less detailed processes, but when combined can be used as an engines for integrated tools of supply chain optimization.

4 Examples of Computer Aided Implementation of Logistics Processes

4.1 Computer Aided Design of Warehousing Process (SCHED) – Micro-logistics

Warehousing processes are crucial elements of supply chains. Designing them means assigning disposed resources (labour and equipment),determining time windows and sequence of warehousing tasks. Warehouse process organization can be then considered as a scheduling problem with many processors, but it significantly differs from classic formulations (compare[1] to [4] or [7]), especially the systems of specific technical constrains and criteria functions characteristic for material handling subsystems are difficult for application.

Application SCHED allows for solving optimization task of scheduling warehousing process with regard to complex of KPIs, especially realization costs for formulated cases and set of specified constrains characteristic for warehousing process. Solving proposed task allows finding rational schedule to cut the warehousing costs while productivity is improved. Additionally organizational assumptions for warehousing process have an effect on the warehouse layout.
SCHED organizes warehousing process in following steps:

1. Defining tasks emerging from client's orders and warehousing technology.
2. Defining the sequence of cause and effect for warehousing tasks with resultant of process constrains and priorities.
3. Assigning optional resources to identified tasks.
4. Warehousing process scheduling with regard to constrains and selected KPIs (genetic programming to find feasible solution).

The main criteria function minimizes daily labour consumption normalized by work costs. The final measure of the quality of warehousing process is total realization cost.

Having data about warehouse tasks and their duration, disposed labour and technical resources and technological constrains a decision makers can use a SCHED application to set and manage efficient and economical warehousing process which is base for capacity planning in supply chains. The following example shows the point.

For a warehousing process consisting of nine tasks one compared different variants of organization. Facility works for 290 days per year for a one working shift per day. Daily work time is divided into twelve 40-minute time intervals. The task parameters and constrains are presented in Table 1.

There are four types of resources assigned to tasks presented in Table 2. Resources have been detailed into labour categories and types of handling equipment.

Warehousing process was organized with regard to task constrains presented in Table 1. Variants of schedule are characterized by different values of criteria function and are classified in Table 3. All calculations were performer with application SCHED. Table 3 gathers appropriate characteristic for each solution.

Figure 2 presents chart of reduced workload for the process in solution no. 2.

Table 1. The parameters and constrains of warehousing process tasks [own study]

Task	Daily number of cycles	Time of single cycle (h)	Task workload (work-hours)	Resource type	Constrains
1	302	0,028618	8,643	1	Minimal realization time 80 min*) Schedule granulation 2 × 40 min. Must be finished before task i = 2
2	302	0,036387	10,989	2	Can't be realized in 1,2,3 time period Schedule granulation 2 × 40 min. Must be finished before task$i$ = 1
3	218	0,00543	1,184	4	Schedule granulation 3 × 40 min. Non-parallel with i = 4
4	145	0,021138	3,065	1	Schedule granulation 3 × 40 min. Non-parallel with i = 3
5	314	0,033953	10,661	1	Schedule granulation 1 × 40 min.
6	338	0,034575	11,686	3	Can't be realized in 11,12 time period Schedule granulation 1 × 40 min.
7	160	0,013862	2,218	4	Can't be realized in 1,2,3,4 t. period Schedule granulation 2 × 40 min.
8	110	0,019397	2,134	1	Schedule granulation 2 × 40 min.
9	198	0,025693	5,087	2	Schedule granulation 2 × 40 min.

*) mandatory for all tasks

Table 2. Resources for warehousing process realization [own study]

Resource type	Handling equipment type	Unit cost of equipment work k^u ($/h)	Labor category	Unit cost of labor category k^u ($/h)	Utilization of working time for a resource
1	1	7,00	1	6,19	0,81
2	2	4,00	2	4,54	0,765
3	2	4,00	1	6,19	0,765
4	0 (manual work)	–	3	7,01	0,9

Table 3. Results gained in SCHED application [own study]

Solution no.	Number of people (labor category)			Number of equipment (type of equipment)		Number of resources (resource = equipment + labor category)				Reduced workload (work-hours)	Annual operational costs ($/year)
	1	2	3	1	2	1	2	3	4		
1	8	5	2	6	7	7	6	3	2	17,377	203775,9
2	8	4	2	6	7	6	5	3	2	16,127	193038,4
3	7	4	2	5	7	6	5	3	2	15,046	178442,2
4	7	4	1	5	7	6	5	3	1	15,046	161782,8
5	7	4	1	5	6	6	4	3	1	14,823	161782,8
6	7	3	1	5	5	5	4	3	1	13,141	151045,2
7	6	3	1	4	5	5	4	3	1	12,632	136449,1
8	6	3	1	4	5	4	4	3	1	11,856	136449,1

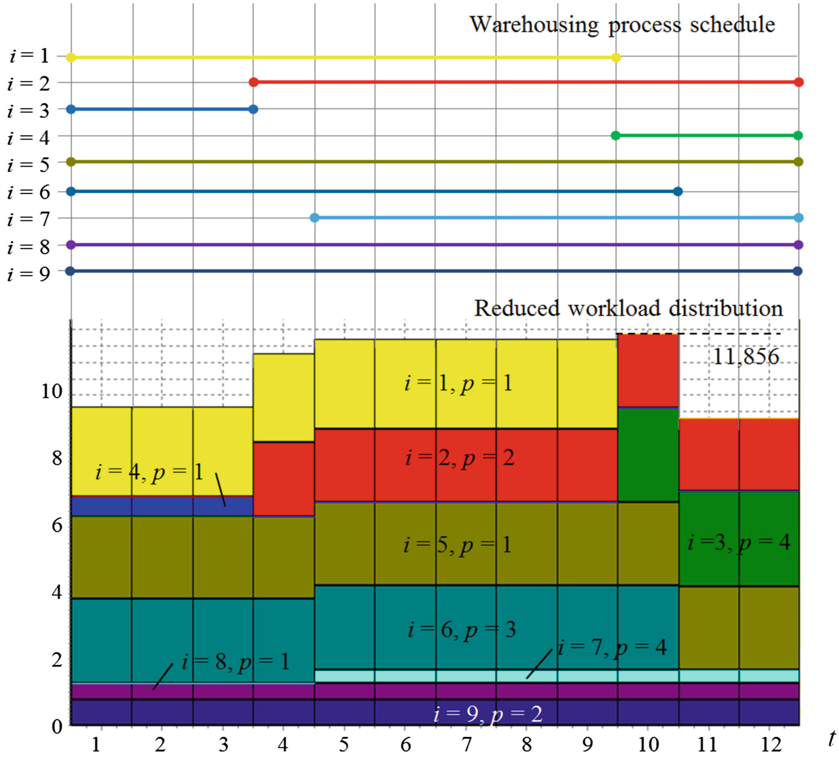

Fig. 2. Warehouse process schedule with chart of reduced workload for solution no. 2 (*i* – task number, *p* – resource number) [own work]

4.2 Computer Aided Organization of Logistics Network for Supply and Distribution of Production Companies by LogMND – Mezo-Logistics

LogMND application supports design of logistics network for production with the location and designing of storage facilities. The algorithm of the application is presented in Fig. 3 and discussed in [15, 16, 18].

Application offers optimization module consisting of two procedures designating the optimal locations of storage facilities and designating rational transportation plan, module for dimensioning of storage facility–can operate independently of other parts of the application and set cost and productivity characteristics, and module of modification storage facility location – a modification of network configuration, to realize logistic tasks with minimum resources. The flow volumes on distribution network are estimated by Busacker-Gowen algorithm.

The LogMND application uses variant data about production needs with detailed information on particular assortments, capacity of suppliers, potential locations of

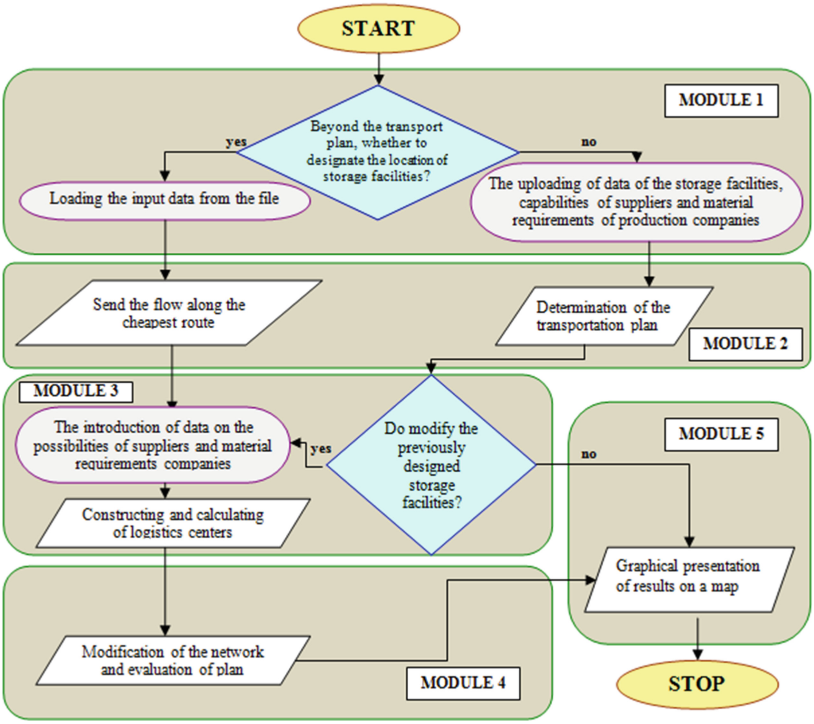

Fig. 3. The overall block diagram of the LogMND computer application [own study]

Table 4. Material needs of production companies in variant approach [own study]

No.	Production company	Variant I	Variant II
		Assortment 1/2/3/4 in option W1	Assortment 1/2/3/4 option W2
1	Baborów	240/140/220/140	300/150/220/180
2	Kamienica Polska	250/340/180/230	380/300/200/300
3	Lipnica Murowana	350/190/250/209	180/400/50/220
4	Kowal	150/270/190/150	250/330/220/100
5	Solec-Zdrój	190/336/320/250	400/500/20/90
6	Stopnica	120/310/230/270	120/80/100/300

storage facilities with terrain limitations and minimum material flow volumes to run a storage facility and transition cost assigned to flow volumes.

The application is used to set potential locations of storage facilities on the logistics network and to set a capacity of those facilities. Additional parameters like warehouse capacity, daily incomes and outcomes, basic dimensions of functional areas of the warehouse, number of equipment and employees, technical and efficiency cost parameters and investment expenditures are set. The program allows for graphical

Table 5. The production capacity of suppliers [own study]

No.	Supplier	Prod. capacity [plu]	No.	Supplier	Prod. capacity [plu]
		Assortment1/2/3/4			Assortment1/2/3/4
1	Kołczygłowy	90/135/250/330	10	Zdzieszowice	176/155/147/70
2	Biała Podlaska	85/133/220/244	11	Bochnia	170/166/220/148
3	Brzozów	117/167/218/231	12	Dydnia	286/90/223/101
4	Bielawa	120/276/150/261	13	Lipsk	275/120/180/90
5	Chodzież	170/156/119/95	14	Czeladź	177/68/128/292
6	Aleksandrów Kujawski	182/201/126/120	15	Łobez	164/230/90/220
7	Lubiszyn	112/150/155/85	16	Wieliczki	103/223/120/219
8	Drużbice	169/197/340/245	17	Oleśnica	134/30/84/90
9	Siedlisko	155/70/239/129	18	Puławy	224/169/137/170

Table 6. Potential locations of storage facilities [own study]

Lp.	Location	Terrain limitations	Min. number of plu required to run a storage facility	Transition cost of plu
1	Czarna Dąbrówka	10000	600	12,15 zł
2	Augustów	9500	500	15,74 zł
3	Korczyn	150000	300	15,33 zł
4	Siewierz	12000	1000	12,22 zł
5	Braniewo	10000	800	41,67 zł
6	Drelów	10000	500	23 zł
7	Santok	9000	600	34,23 zł
8	Zelów	10000	400	17,06 zł

Table 7. Selected parameters of storage facilities obtained from the **LogMND**, variant I/II [own study]

	Variant I/II	Variant I/II	Variant I/II	Variant I/II
Parameter	Drelów/Augustów	Korczyn/Korczyn	Siewierz/Siewierz	Zelów/Zelów
Warehouse capacity (pallets)	1014/1220	4921/4077	2883/3406	2544/2424
Daily pallet input	152/183	739/612	433/511	382/264
Daily pallet output	178/214	862/714	505/596	446/425
Daily return of empty pallets	21/25	100/83	59/69	52/50
Total expenditures	1843036/2100012	6781062/5543274	4010110/4833476	3794504/3560540
Annual exploitation costs	359854/415565	1477849/1176019	814639/1045014	793078/739669
Total cost of labour	329280/403760	1540560/1211280	807520/1062320	807520/733040
Average transition cost per pallet	19,43/19,19	17,53/16,73	16,08/17,68	17,98/17,36
Cubature per pallet	6,11/5,83	4,5/4,53	4,77/4,6	5/4,9

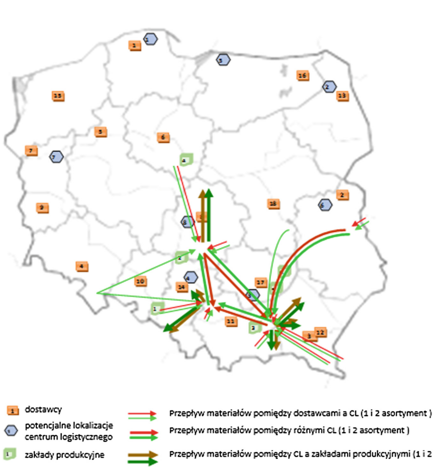

Fig. 4. Flow volumes between elements of logistics network in variant I in assortment structure 1 and 2 [own study]

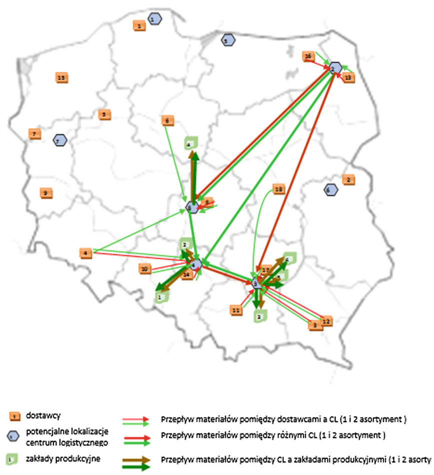

Fig. 5. Flow volumes between elements of logistics network in variant II in assortment structure 1 and 2 [own study]

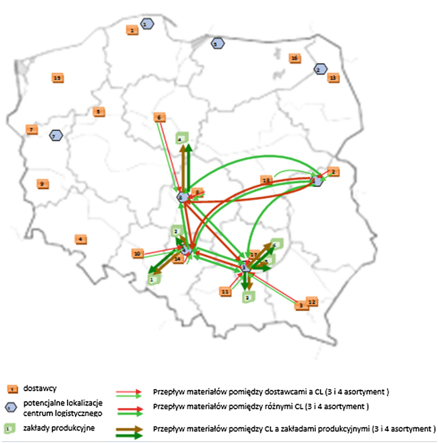

Fig. 6. Flow volumes between elements of logistics network in variant I in assortment structure 3 and 4 [own study]

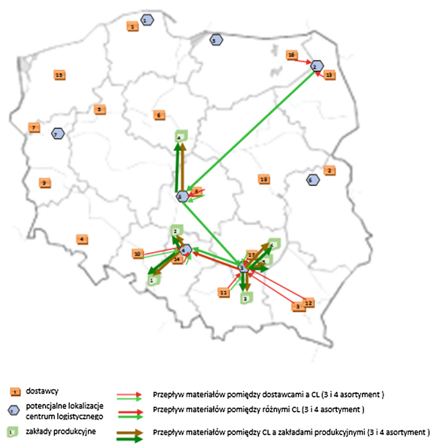

Fig. 7. Flow volumes between elements of logistics network in variant II in assortment structure 3 i 4 [own study]

illustration of material flows, locations and characteristics of designed system. Detailed examples of usage are presented in [17].

The implementation of the LogMND can be presented on the example. Table 4 presents material needs of production companies. The locations of suppliers and their supply possibilities are given in Table 5. Locations of potential storage facilities, including terrain limitations, unit costs of transition and minimum number of required units are presented in Table 6. As a result of the optimization decision maker gets from

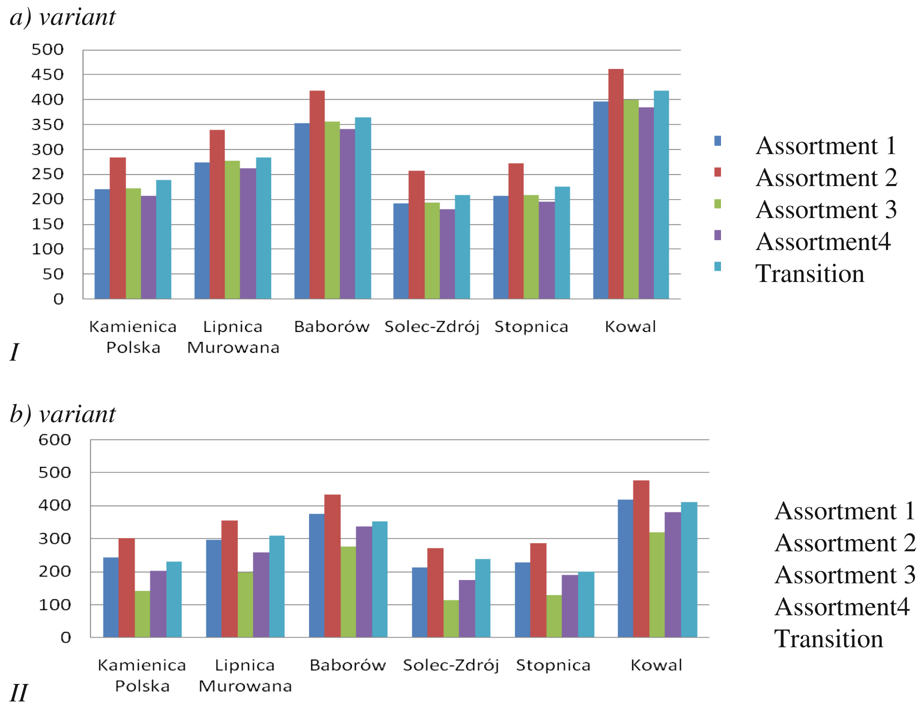

Fig. 8. Unit costs of distribution in logistics network for variant locations [own study]

LogMND location of particular storage facilities with detailed information about technical and economic parameters (Table 7).

Additionally decision maker knows dimensions of functional areas of the warehouse, areas and cubature of the building, number of equipment and labour, detailed information about costs and expenditures. Figures 4, 5, 6 and 7 present flow volumes between network elements while Fig. 8 presents costs of distribution.

5 Conclusion

Presented tools are tailored to special applications, therefore can be extremely useful for decision makers in studying complex logistics systems starting from defining their elements up to the systems influencing regional economy. They allow quickly and without lot of work to determine whether the newly designed system will operate without interruption and ensure the implementation of assumed logistics tasks. Tailor-made tools are an important condition of analysis variants of logistics system organization and technology.

Presented tools enable not only the designing of selected elements of the logistics system but also allow assessing their operational effectiveness. Decision support with computer techniques for companies of TSL market is necessitated by searching for optimal solutions, while increasing productivity and trading of their companies. This applies to both large and small companies.

Applications can support designer's work in solving problems of different level. Detailed example touches the problems of logistics network configuration for transport and warehousing services with particular emphasis put on the location of objects like distribution centres, hubs, and intermodal terminals.

Presented applications allow solving problems on different levels of difficulty and complication. These kinds of solutions can be a base for advanced planning applications prepared for specified usage by network developers.

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