DOI: 10.26411/83-1734-2015-2-38-6-18

Logistics Engineering in Logistic Processes Designing

Edward Michlowicz
AGH University of Science and Technology, Krakow

Leszek Mindur
The International University of Logistics and Transport in Wrocław

In the systemic approach, each enterprise, (production, transport, commercial) is a complex system of objects and relations between these objects, as well as between the system and its surrounding. As a result of the multitude of variables and indicators of the company's performance assessment, the methods of formalizing the existing relationships are still being sought for. Logistics engineering is the field of knowledge which, through the integration of many processes, enables finding practical solutions. It is a rarely used term in Poland, meanwhile, for example in the USA, logistics engineering, using mathematical methods, learning achievements is a commonly used tool, supporting business operations. The article presents primary tasks and possibilities of logistics engineering.

Key words: logistics, system, logistics engineering, lean methods

1. INTRODUCTION INTO LOGISTICS ENGINEERING

Each enterprise operates in a specific environment (close and distant). In terms of supply chains, this means that it is a link of a specific chain. The effectiveness of the company's operation depends on many factors, including, first of all, technical and economic ones. Logistics processes, occurring both outside and inside a company play a key role. The qualitative evaluation of these processes is necessary to determine the importance of the company on the market (global or local). However, to determine the main indicators of the company's performance assessment, it is necessary to use and apply, in a skillful way, the quantitative methods, elaborated by modern science and technology. In Logistics Engineering Handbook [1], G. Don Taylor wrote: *The fact is that there are few, if any, significant differences between business logistics and logistics engineering, except that logistics engineers often use more "mathematical" or "scientific" rules in logistics applications. In the search for logistics solutions, the wider recognition of logistics is a challenge for the future, as reflected in the overall system approach"*

Process design within logistic systems is a complex, interdisciplinary and multifaceted issue [2]. In the processes of designing complex systems, it is necessary to use:

– logistics engineering,
– systems theory.

Contemporary, the expression *engineering* acquires a broader meaning than the traditional reasoning of this concept, according to which, *engineering* - is the activity of designing, constructing, modifying and maintaining cost-effective solutions for practical problems, using scientific and technical knowledge. The new PWN Universal Encyclopedia [3] states that in general, the term 'engineering' defines *"technical creation, the result of which is an object (prototype), method of production (technology) or change of environment"*. Thus, the combination of engineering and the area of creative activity resulted in the creation of new, unknown until recently, terms, such as*: biomedical engineering, genetic engineering and even engineering of sociology.*

The term *logistics engineering* is rarely used in Poland, unlike in the USA, where *logistics engineering* is widely used to solve various tasks, related to design and implementation of logistics processes. For many years the organization *The Council of Logistics Engineering Professionals* – CLEP [4] has been existing in the USA.

According to CLEP: *Logistics Engineering: The professional engineering discipline responsible for the integration of support considerations in the design and development; test and evaluation; production and/or construction; operation; maintenance; and the ultimate disposal/recycling of systems and equipment. Additionally, this discipline defines and influences the supporting infrastructure for these systems and equipment (i.e., maintenance, personnel, facilities, support equipment, spares, supply chains, and supporting information/data). The practice of logistics engineering is exercised throughout the system life-cycle by conducting the iterative process of supportability analysis and the accomplishment of trade-off studies to optimize costs and system, logistics, and performance requirements.*

In addition, CLEP characterizes a logistics engineer as a professional, who has the knowledge and skills, necessary for effective application of scientific and mathematical rules, in quantitative and qualitative analyzes, and who can reasonably deduct when developing and implementing solutions for practical problems in the field of logistics engineering.

Activities should be focused on "*how*":

- how the product is made,
- how the service is provided.

Therefore, the task of logistics engineering in an enterprise is to develop and prepare a system of activities, which, using the principles and laws of logistics, as well as other areas of, broadly understood, science, will enable implementation of logistical tasks, supporting the achievement of effects, defined in the enterprise strategy.

The following basic strategies can be listed:

- customer service high quality,
- production achieving world-class manufacturing (World Manufacturing Class),
- achieving the desired (specified) productivity,
- obtaining determined, economic and technical indicators.

Logistic methods and tools, helpful in enterprise logistics, are generally known [5, 6, 7, 8, 9].. Their application depends (apart from the adopted strategy) on possibilities, knowledge and skills of technical and managerial staff as well as on the area of adopted activities. The choice of both the area and methods of task implementation is the first, crucial stage of activities, whose aim is to achieve the desired effects.

Other quantitative solutions suggest different disciplines less related to logistics, including-

- operational research (OR),
- artificial intelligence (AI),
- information technology (IT).

2. SYSTEMIC APPROACH TO ENTERPRISE AND LOGISTICS

The word, term system is often used in science and practice, although it is not necessarily clearly defined. The primary reason for the appearance of this term was the development of science of activities and cybernetics, as well as the need for a concept that would introduce order in discussions of increasing complexity. Weinberg [10], proponent of systemic thinking, describes, that the system is often understood as a whole, part of a larger unity, made up of parts (smaller unities) connected in a way that gives it a certain structure, and separated for the sake of certain functions assigned to these entities.. This isolation, or identification, consists of including in the analysis or in designing, exclusively those links which, due to the purpose of a given system, are interesting, or in other words, relevant The concept of general system theory introduced by L. von Bertalanffy [11] is currently understood in two ways, namely as the general theory of systems and the theory of general systems. The general system is in this case understood as a system, which has identified links, forming a specific structure, while system components are unidentified. The importance of general problems regarding the system as a whole increases with their complexity. The theory of complex systems (or large systems) deals with these issues. Currently, there is no general, strict definition of a complex system. It is assumed that the system is complex if it consists of a large number of interrelated and interacting elements.

In the case of a system, consisting of *n* elements, n (n - 1) possible connections between these elements should be considered. In work [12] S. Ziemba, after W.R. Ashby, divides all possible systems into two categories:

- *configuration, pattern systems - ordering, relational, static,*
- *acting systems - operational, processing, process and dynamic..*

The purpose of each operation is, in a general case, to produce a certain change in the passage of reality. The essence of the acting system is its purpose, the task, which is established. In addition, in operational systems it is possible to form entities, objects, tools and operating conditions in which the process of processing objects of action is implemented. They are brought to the system's *entrance* and transformed into objects that after system "having flown" through the system appear at its *exit*. All systems have one common criterion: the flow of information in the control between two basic elements: the object, in which the work process takes place, and the control system, in which the process takes place.

In the manual considered canonic for logistics environment, *Logistics Systems*, H.-Ch. Pfohl [13] formulates the system in a very descriptive way. The preparation of products takes place through production processes (acquisition, processing) in industrial enterprises. The products are subject to qualitative transformation. The distribution of products is the connection between preparation of products and their consumption. It takes place through the processes of transformation (movement and storage), which cause the transformation of goods not in the qualitative, but in time-space sense.

According to Pfohl: "logistics systems are systems of spatial-temporal transformation of goods". They occur in so-called logistics companies. These are service enterprises, whose aim is to provide spatial and temporal linkages. They also take place in production, commercial or service enterprises, in which the fulfilment of temporal and spatial needs is only part of the tasks aimed at meeting the proper purpose of the enterprise. The result of logistics processes is the flow of goods, which combines the systems of both preparation and use of goods. Information flows occurring in logistics systems whose objects are tangible goods, are not the aim in themselves, but are related to the physical flow of products.

The proper definition of a system (micro-logistic, meta-, macro-logistic) is conditioned by the knowledge of the aim, in which the system should be determined, on the object under study, as well as by the selection of the appropriate level of abstraction. In defining a logistic system it is necessary to establish at least two classes of issues:

- the type of system under consideration, due to its institutional nature (micro-, meta-, macro-logistics),
- area of application of the system (technique, organization and planning, scientific and research work, epistemological area).

According to the author [9], the Logistics System of the Enterprise can be written in a topological approach as follows (as a super-system):

LSE = <MFS, MS, IS, R >

where:

MFS - material flow system,

SZ - management system,

SI - information system,

R - relations between systems and between systems and the environment.

Fig. 1 shows the interrelations of supply subsystems, production and distribution of products with management subsystems MS and information IS.

The MFS material flow system has been defined through subsystems of orders and deliveries, task implementation and distribution of finished products:

MFS = {SOS, PS, DPS},

where:

SOS - is a system of orders and supplies of materials,

SP - is a system of production task implementation,

DPS - is a system of finished products distribution and picking

In particular systems, all tasks performed in the subsystems should be included. For example:

PS system (production - production task accomplishment) – is created by subsystems of production, transport and storage, waste:

PS = {PSS, TSSSWSS},

In the PS, production system –the following, among others, in the production subsystem are considered:

- production technology and relations between tools,

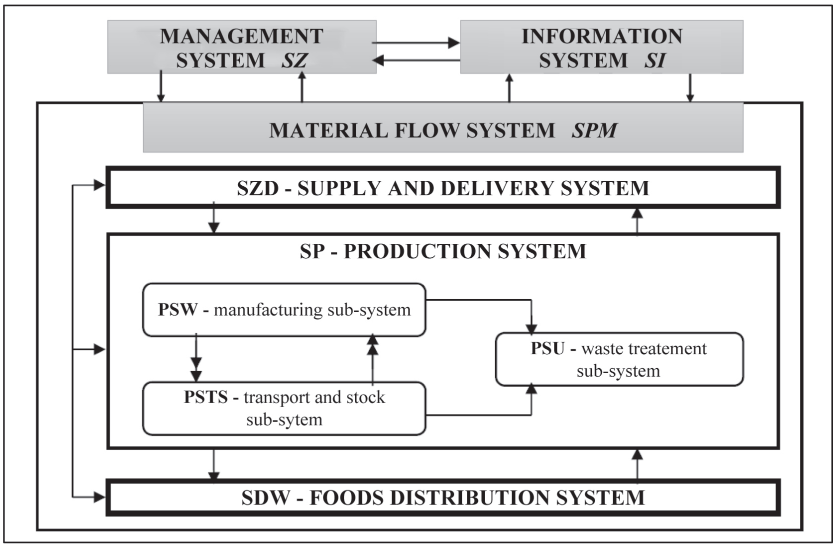

Fig. 1. Simplified structure of a production system - LPS

- characteristics of production equipment (material processing time, changeover time for other production, repairs, failures),

In the TSSS transport and storage subsystem:

- operational characteristics of tools (repairs, failure),
- transport cycles for the adopted structure of transport routes,
- characteristics of inter-operational storage sites (location, capacity, method of storage).

Each system works in a specific environment. In systems research, only the impact of the so-called close environment is defined. Meanwhile, the functioning of the production system takes place in a double environment [14]:

- close (environment of the first degree) - it is an enterprise system in which the production system (subsystem) has been separated,
- far (surroundings of the second degree) - is a system in which the enterprise operates.

Using the simplest system definition in terms of system theory and introducing into this definition elements presented in Fig. 2, we obtain a more developed form of the production system (in the vicinity of the supply chain):

PS = < {X, Y, T, Z}, R > ,

Figure 2 shows the general form of the production system, with the exemplification of elements and links.

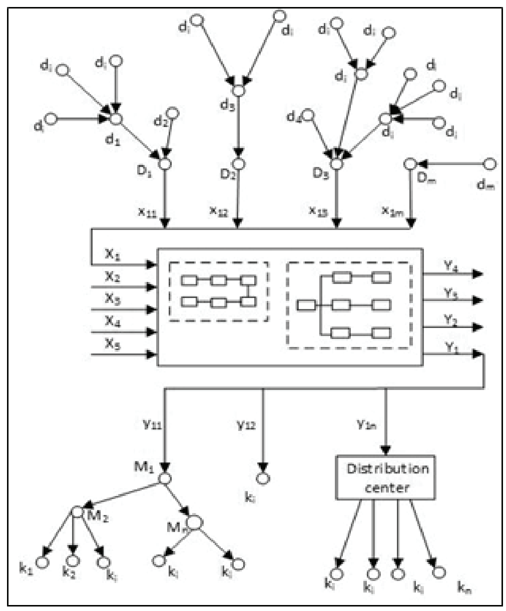

Fig. 2. The production system within the supply chain

where:

X ={X1, X2,... Xi, ...XM}; for i = 1,…M – set of external magnitudes describing the input elements (materials and parts, equipment, personnel, information, capital, energy); as a way of example

X1 = (x11, x12, ….x1k, …x1P); for k = 1,…P – set of material, parts and components supplied to the production system X2 = (x21, x22, ….x2l, … x2R); for l = 1,…R – set of equipment,

Y = {Y1, Y2,... Yj, ...YN}; for j = 1,…N – a set of external magnitudes describing output elements (finished goods, services, production waste, information);as a way of example

Y1 = (y11, y12, ….y1m, …y1Q); for m = 1,…Q – set of finished goods,

T = {T1, T2, ... Tn, ... TS}; for n = 1, ... S - a set of external quantities describing the elements of the input vector processing into the output process (technological, transport, storage, control and service operations);

Z = {Z1, Z2, ... Zo, ... ZU}; for o = 1, ... U - set of external quantities describing elements of the management process (planning, organization, control, control),

R = (RX × RY × RT × RZ) – material, information feedback (relationships) between elements (X, Y, T, Z) of the SP system.

Logistic goals, related to production processes, are related to - Key Performance Indicators. There is a clear conflict between KPIs and logistics goals, hence, for each case, it is necessary to consider mutual relations.

Three interrelated processes are considered

- production and testing (research)
- transport,
- warehousing and supply.

The links between the production level in the course of WIP (work in progress), minimization of processing times and material passage through the equipment, and the level and reliability of deliveries are of particular importance. The important obstacles preventing the realization of sourcing strategy are long delivery times of critical materials that result in longer forecasting horizon for material planning and the necessity to maintain inventory high levels for these materials.[15]

For the settlement of possible conflicts, Nyhuis [6] proposes the use of logistic operating curves (LOC - Logistic Operating Curves). They are created for all correlations between the chosen parameter (goals or variable) and the independent variable (for example, a curve: time of transition - WIP or costs of storage - resources).

Additional curves taking into account logistics processes in the production system are:

POC – Production Operating Curves

TOC – Transport Operating Curves

SOC – Storage Operating Curves

The logistic approach to the problems of material flows creates the need to introduce new concepts and measures, the use of which would allow proper assessment of the actual situation of the company, including costs incurred, losses and profits, and would indicate ways to improve. The assessment of these magnitudes, setting their interactions and their impact on the final effect of implementation and the cost incurred, requires the use of appropriate mathematical models of material flow analysis [16].

3. LOGISTICS METHODS AND TECHNIQUES IMPROVING COMPANY'S ACTIVITIES EFFICIENCY

A feature that characterizes enterprise management in recent years is the constant search for methods that improve the efficiency of operations. The development of the SCM (Supply Chain Management) concept forces enterprises to transform - from functionally oriented organizations to process-oriented organizations. In addition to the technical sphere, the field of knowledge that contributes in a large extent to the area of productivity improvement of manufacturing enterprises is production logistics. In many studies dealing with enterprise logistics, the most attention is paid to processes related to orders, material procurement, purchases, storage and distribution of products. Meanwhile, in a production enterprise, the process in which most capital is involved is the production of products. As a result of manufacturing, in the production process, the main stream of materials flows through individual production cells (positions) of the enterprise. This flow depends on many factors, from which the structure of the production system has the most influence on the flow processes.

The common element that combines different approaches to production logistics is property flow. Hence, new concepts and tasks of production logistics arise. As a way to eliminate waste (muda) J. P. Womack and D. T. Jones [17] recommend the lean approach (lean thinking) by creating a stream of values in the enterprise. Lean may be defined most simply as a process of continuous elimination of waste. The most important task in manufacturing systems is the maintenance of continuity in the flow of materials, as well as the constant improvement (kaizen) of continuity.

Fig. 3 presents a simplified scheme of the system covering the key processes, in which it is possible to

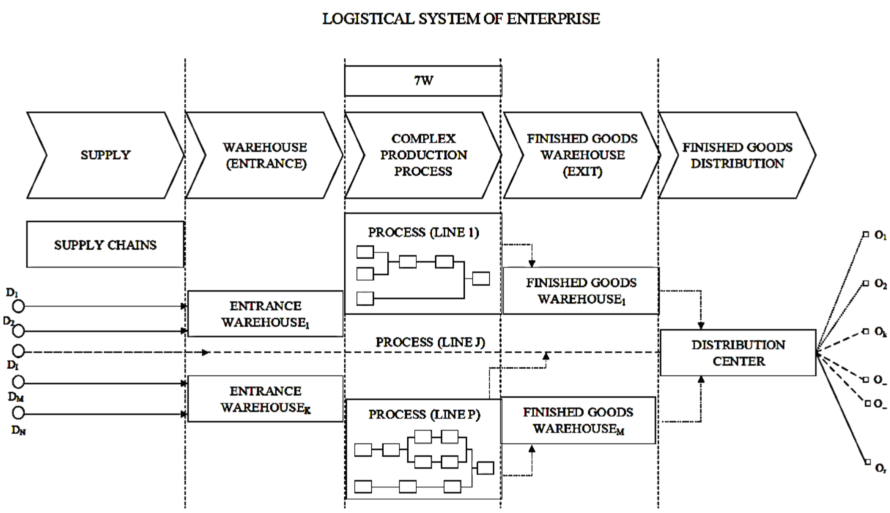

Fig. 3. Diagram of logistic processes of the company

The basic tasks, necessary to carry out the improvement of the functioning of the production system in such a formulated system, are presented in Table 1.

Table 1. Basic tasks to be implemented in the production system (after fig. 3)

Basic tasks to be implemented				
Supply strategy (choice of suppliers)	Warehousing strategy (warehouses)	Production strategy (material flow continuity)	Warehouse strategy (warehouses)	distribution strategy (distribution centres)
Classification of components (ABC, XYZ, **Pareto)**	admissions technology (including identification)	Basic Laws of Production Logistics (9 PLP)	stocks analysis	picking
Forecasting	stocks model	WIP	storage technology	Model of dispatch and customer service
	location (ABC)	lean toolbox (VSM, TPM)		Reverse logistics
	Means of transport	ZSI (MRP, ERP)		optimization (VRP)
Computer assistance - common hardware and software platform Indicators of efficiency evaluation				

implement the laws and rules of industrial logistics

Currently, there are many methods and techniques that can be used in the company's production activities. Therefore, the right choice (for a company or a process) is often difficult. The extensive publication of various tools, techniques and methods supporting the lean concept was presented by J. Bicheno and M. Holweg: *The Lean toolbox: The Essentials guide to Lean transformation*[5].

The experience of the authors leads to the conclusion, that the task of introducing the flow continuity improvement can be described in several steps. In the first stage, it is necessary to precisely identify all processes related to production and logistics. After identifying and setting current targets for improving production efficiency, there should be an appropriate choice of methods and tools to achieve these goals.

Therefore, the initial activities include two stages:

Stage I – Process identification – the tasks: 1 – 2 – 3 – 4

1. Selection of process for analysis.

2. Making a detailed diagram of the technological process

3. Collection of process data, such as: orders, deliveries, stock, etc.

4. Designation of the primary parameters and values describing the process, providing the required time study for the durations of operations.

Phase II – Selection of improvement methods and tools – (for example VSM, TPM) should include the tasks 5 and 6

5. Description and analysis of losses and waste in the process (for example 7 muda, 6 big losses).

6. Selection of the right tool

Fig. 4 presents the first two stages of the algorithm enabling the improvement of productivity in the production system.

The implementation of individual lean elements (for example 5S, JiT, Kanban, TPM, VSM) is the beginning of the way to realize the full concept. The real challenge is seeing the entire process. In the case of many companies, especially small and medium enterprises, a full view of the process may turn out to be a difficult task. There is, therefore, a way to implement individual elements. In order, for this path, to result in synergy, it is worth building a system of goals for a longer period of time and defining individual stages for this period. Quick effects are achieved, for example by eliminating waste (7M, 3M) and introducing the organization according to the rules of 5S.

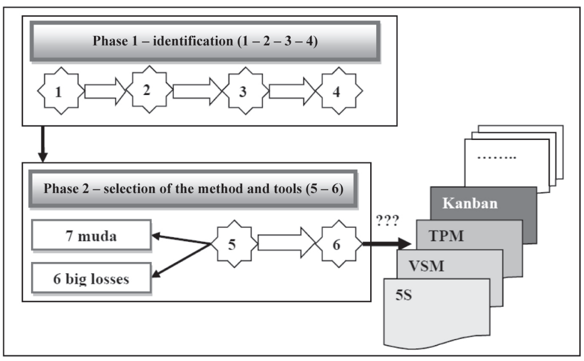

Fig. 4. Diagram of the algorithm for selecting the method of flow continuity improvement

The process of accomplishment is accompanied by the stream of values. The value stream is a set of all actions required to produce a specific product. The imaging of the value stream allows to notice all kinds of waste in it, and to direct further “slimming” activities to eliminate waste from the area of value adding processes. Figure 5 presents the steps of the algorithm for selecting the VSM (Value Stream Mapping) method.

One lean process management tool for companies is the Total Productive Maintenance method.

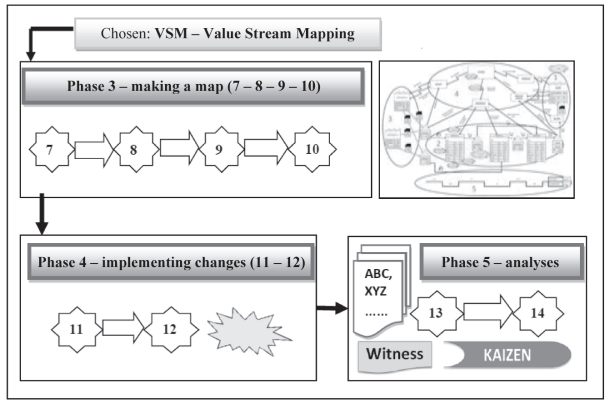

Fig. 5. Schematic presentation of the improvement algorithm - use of VSM

The goal of TPM is the pursuit of maintaining operational continuity of equipment and machines that perform specific tasks, which is also related to the improvement of their operational efficiency. The fig. 6 represents Algorithm: improvement of performance using the TPM method (Total Productive Maintenance).

In addition to the methods known as the lean toolbox, logistics engineering proposes analyzing

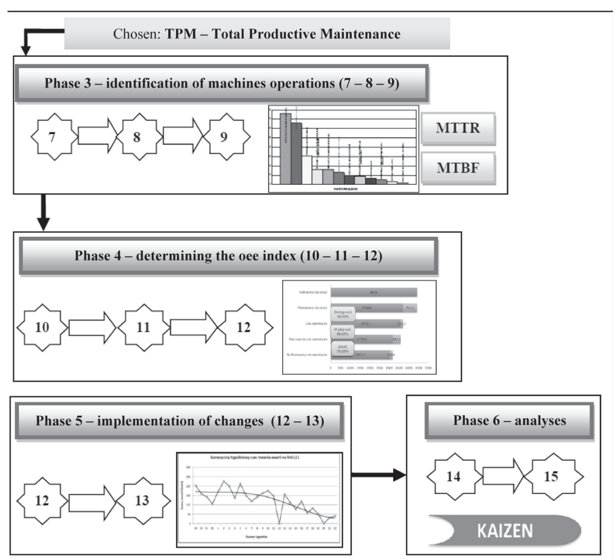

Fig 6. Algorithm: improvement of performance using the TPM method

the course of manufacturing processes, using production logistics (9 PLP). According to P. Nyhuis and H.P. Wiendhal, production logistics law (PLP) are universal statements, describing the relationships between individual parameters of production process. Currently, it is assumed that what is desired is to reduce works in process (WIP), to shorten and unify the transition times and to unify the Work Content structure. In fact, local goals may be different, depending on the conditions and priorities adopted in enterprises for individual processes, but in most cases the assumptions made are true. Table 2 summarizes the logistics principles of production, according to Nyhuis and Wiendhal [6].

Table 2. Basic laws of Logistics and production PLP

1PLP	–	In the long term, the entry levels of the materials entering the position and leaving the position must be balanced.
2PLP	–	The time of transition of material through the position depends on the rate of the work in progress (WIP) to the rate of output from the process
3PLP	–	Reducing the utilization of a position enables a disproportionate reduction in WIP jobs and shortens the transit time of material through this position
4PLP	–	Variance and average value of the labour intensity of the task define the logistic potential of workstation and position
5PLP	–	The size of the work in progress (WIP) buffer required to ensure the proper utilisation of the position depends chiefly on the flexibility of the load and efficiency of the position
6PLP	–	If orders are fulfilled according to FIFO principles, the time between operations does not depend on the labour intensity of individual operations.
7PLP	–	Applying sequential rules can significantly affect the average transit time only at a high level of work in progress and a wide range of distribution of labour intensity of tasks.
8PLP	–	Variance in transit time depends on the sequential rules applied, the level of work in progress and distribution of the labour intensity of the tasks.
9PLP	–	Reliability of the logistics process is determined by the mean value and distribution of time of material transit through the system.

4. NON - LOGISTICS METHODS IN THE DESIGN OF LOGISTIC PROCESSES

The task of distribution is to provide final buyers with the products they want (type, quantity) to the places where they want to purchase them, on agreed time, on agreed terms and at the lowest possible price. Therefore, it is the task of the logistic operator to establish a freight transport plan that would give optimal results due to the adopted optimization criterion. In addition, there are often many other decision-making problems to be solved, including, among others:

- problems of minimizing transport times,
- problems in shaping the transport network,
- problems of spreading the traffic flow in the network,
- issues regarding selecting technological equipment and determining the potential of transport and logistics systems.

In a situation, where an enterprise has only one distribution centre from which it delivers goods to the market, determining the optimal transport plan is connected with finding the shortest path between individual buyers.

If, however, there are more such distribution centres, the aim of the task is to determine, which centre the recipient should be supplied from, and in what order the recipients should be "served", so that transport costs are as low as possible, taking into account the resources available at distribution centres [14, 18]. In this case, the optimal solution to the problem, considering its computational complexity, is a very difficult task. Therefore, for a certain period, in order to solve such problems, the tendency of finding the algorithm providing optimal solutions is weaker, while approximate solutions, appropriately close to the optimal solutions, are searched. The weakening of the optimality condition often allows reducing computation time, from exponential to polynomial, with little loss of optimality. The approximate algorithms, based on artificial intelligence, are the only realistic way of solving computationally difficult problems of large dimensions.

The development of the tasks of the Travelling Salesman Problem (**TSP**) is the problem of many **MTSP** (Multiple Travelling Salesman Problem). In the **MTSP** problem, the task is accomplished by many travelling salesmen, each of them initiating and completing a route in the same warehouse.

In real logistics systems there are many limitations, not included in typical algorithms [2], such as, for example, the imposed delivery date, the capacity of the means of transport, the dimensions of the loading units. This results in a constant search for new algorithms to support the implementation of complex logistic operators' tasks.

The most known, typical problem of **VRP** (Vehicle Routing Problem) supply is to minimize transport costs from one warehouse to any number of recipients (customers). In the VRP task, each means of transport (vehicle) has a defined payload and the customer needs. Thus, the total demand of customers cannot exceed the capacity of the means of transport. In general, the solution consists in minimizing the number of vehicles, the number of routes and the total length of routes. Currently, there are many varieties of delivery problems. The most well-known are:

- The problem of deliveries with defined **CVRP** (Capacity Vehicle Routing Problem) vehicles - all vehicles have identical payloads,
- **OVRP** (Open Vehicle Routing Problem) open supply problem - the task ends after servicing the last customer; the vehicle does not return to the initial warehouse,
- The problem of deliveries with time windows **VRPTW** (Vehicle Routing Problem with Time Windows) - CVRP extension with time windows for each client (time interval in which the client can be served),
- The problem of deliveries with various vehicle capacities **SDVRP** (Site-Dependent Vehicle Routing Problem) - **CVRP** extension; vehicles have different capacities, hence the limitation in the service of some customers,
- Multi-warehouse problem of supply of **MDVRP** (Multi Depot Vehicle Routing Problem) - there are many central warehouses,
- The problem of deliveries with many warehouses with **MDVRPTW** time windows (Multi Depot Vehicle Routing Problem with Time Windows),
- Stochastic delivery problem of **SVRP** (Stochastic Vehicle Routing Problem),
- The problem of deliveries with stochastic needs **VRPSD** (Vehicle Routing Problem with Stochastic Demands)
- The general problem of deliveries with **RDPTW** (Rich Delivery Problem with Time Windows) windows - customers have windows defined, the mass of the loading unit is defined, and the vehicles have different load capacities.

In other versions of the RDPTW problem, the existence of many warehouses, cargo units and vehicles are additionally described in dimensions, and the vehicle receives cargo only from one warehouse, where it begins and ends the implementation of the logistic task. The solution to the problem is to minimize three criteria:

- number of vehicles,
- the total length of routes (routes) of all vehicles,
- the cost of the task (or a defined cost index).

Various hybrid algorithms are currently used to solve such complex problems. These are most often genetic, evolutionary, adaptive searches of the large ALNS class (Adaptive Large Neighbourhood Search) and *heuristic simulated annealing* (Simulated Annealing) and *ant algorithms* (Ant Colony Systems). The task can be considered in many ways, depending on the problems being considered.

5. SUMMARY

In modern enterprises, logistics competences cover an increasingly growing area. The, broadly understood, supply and production chain management, currently offers many different methods and techniques, whose aim is to improve the functioning of logistics systems. Some of these methods have been developed as a part of Lean Management. Systems related to the organization and control of material flows are commonly known, and as a way of example, the following can be listed: Five pillars of visualization 5S, 7 Muda (waste), SMED (quick changeover), 5W + 1H (why and how), JiT (just in time), Kanban (control through cards) or integrated IT systems of MRP, ERP class. Logistics of production is also facing these challenges. Improvement of value streams through the use of VSM mapping methods and maintenance of machines in high efficiency TPM, are increasingly used techniques in manufacturing enterprises. In many areas the production logistics laws and original flow analysis algorithms are very helpful tools. The development of strategies, related to supply chains and lean thinking, forces to go beyond the enterprise. This leads to the systematic recognition of problems related to the design of logistics processes. The field of knowledge which, through the integration of many processes, enables finding practical solutions, is logistics engineering, using mathematical methods, as well as learning achievements related to the, broadly understood, logistic processes.

LITERATURE

[1] Taylor G. D., (2008), Logistics Engineering Handbook, CRC Press Taylor & Francis Group, Boca Raton

[2] Jacyna M., Lewczuk K. (2016),Projektowanie systemów logistycznych, Wydawnictwo Naukowe PWN SA, Warszawa

[3] Praca zbiorowa (2004), Nowa Encyklopedia Powszechna PWN, Wydawnictwo Naukowe PWN, Warszawa

[4] www.logisticsengineers.org – strona CLEP

[5] Bicheno J., Hollweg M. (2008),The Lean Toolbox: The essential guide to Lean transformation, Picsie Books, Johannesburg

[6] Nyhuis P., Wiendhal H.P. (2009), Fundamentals of Production Logistics. Theory, Tools and Applications, Springer – Verlag, Berlin Heidelberg

[7] Michlowicz E., Smolińska K., Zwolińska B., (2015), Logistics engineering in a production company, Research in Logistics & Production Vol. 5, No. 5, pp. 503–513.

[8] Gudehus T., Kotzab H., (2009), Comprhensive Logistics, Springer-Verlag, Berlin Heidelberg[9] Michlowicz E., (2012),Zarys logistyki przedsiębiorstwa, Wydawnictwa AGH, Kraków

[9] Weinberg G.M., (1979), Myślenie systemowe, WNT, Warszawa

[10] Bertalanffy L., (1984), Ogólna teoria systemów, PWN, Warszawa

[11] Ziemba S., Jarominek W., Staniszewski R., (1980), Problemy teorii systemów, Zakład Narodowy im. Ossolińskich – Wydawnictwo, Wrocław

[12] Pfohl H.-Ch., (1998), Systemy logistyczne, Wydawmictwo ILiM, Poznań

[13] Mindur M. (red., 2017), Logistyka. Nauka-Badania-Rozwój, Wydawnictwo Naukowe ITeE-PIB, Radom

[14] Mindur L. (red., 2014),Technologie transportowe,Wydawnictwo Naukowe ITeE- PIB, Radom

[15] Pawęska M., Tubis A., Kazimierowicz R., (2013) Wydawanie „na zeszyt" w epoce systemów ERP, Nowoczesny Magazyn nr 4 (88), Warszawa

[16] Mindur L. (red., 2014),Technologie transportowe,Wydawnictwo Naukowe ITeE- PIB, Radom

[17] Womack J.P., Jones D.T., (2008), Lean thinking – szczupłe myślenie, ProdPress.com, Wrocław

[18] Mindur M. (red., 2012), Logistyka. Infrastruktura techniczna na świecie,Wydawnictwo Naukowe ITeE- PIB, Radom

Date submitted: 2018-......

Date accepted for publishing: 2018-05-21

Prof. Edward Michlowicz
AGH University of Science and Technology Krakow

Prof. Leszek Mindur,
the International University of Logistics and Transport in Wrocław