APPLICATION OF LOGISTICS PRINCIPLES WITHIN TECHNOLOGICAL PROCESSES DESIGN.

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https://doi.org/10.37904/clc.2022.4548

Abstract

The article addresses the methodology of synergistic design of complex and advanced production systems as a basic approach to technological logistics. Generically, it further develops process of generalizing the author's 25 years of practical experience in designing and logistics optimization of technological processes and summarizes the results of more than 150 research and innovation projects, solved in the past. The topic deals with the transfer of knowledge from logistics to the design of new technologies and processes. At the same time article brings applicable output from analytic technological review of logistics and a summary of results, which create extensive innovative opportunities for both research and industry.

Keywords: Logistics principles, technological logistics, design of technological processes

1. INTRODUCTION

The basis of the philosophy of logistics represents a tool for understanding and controlling any system through the coordination of flows and links between system elements taking place in particular system. Described access follows the flows between the system and its environment and it can be summarized in five basic logistics principles: system approach, coordination principle, multicriteria optimization, planning and algorithmizing. This division was defined by prof. D. Malindžák in 1996 in his book Industrial Logistics. This revolutionary new approach has ushered a new era of logistics in flow coordination. In line with this approach, the elements of the system (transformation technological operations) are viewed as black boxes, which are interesting only as terms of their inputs and outputs.

The ambition of this article as well as of the entire technological logistics is to look at these black boxes as separate systems. The key approach of this article is to introduce into industrial practice the need to coordinate flows in these separate systems and the need to implement logistics at the lowest technological level. The basic level of this technological level is the level of elementary physico-chemical and mechanical processes. For example, in the heat treatment of raw materials, it is possible to divide logistics processes according to a coordinated and controlled flow into rheological (material flow), hydromechanical (medium flow) and thermodynamic (heat flow) processes, with the technological operation being a change in physical and chemical properties.

The key benefit of technology logistics is the concentration of the problem solution directly in the physical, executive area, which forms the essence of the process. Solutions at higher hierarchical levels can only be optimized based on the lowest technological field only. The benefits achieved by technological logistics solutions can reach up to high percentage (double-digit) of the technological processes’ costs. This confirms the great innovation potential of technology-oriented logistics.

In recent times the technological processes separated design with minimal regard to logistics is the predominant element technology designers utilizes. From the logistics systems design point of view, technological operations act as black boxes. Such a separate approach does not create possibility fully utilize innovation potential (above-mentioned), which is precisely hidden in the synergy of the system. (In synergistically functioning elements of the system). Synergy needs to be designed and achieved at all its hierarchical levels of the system, but especially at the lowest levels. The use of this potential for streamlining is conditioned by the design of complex technological and logistics systems by a holistic, (truly systemic) approach.

Long-term work in research and innovation of production processes motivated me to try different approaches and design methodologies, which over time have been transformed into my own, already mature methodology of technology design, driven by a "logistics" approach. This methodology is process approach based, which in turn is conditioned by a thorough knowledge of the process. Experience is underlaying, that there is a direct relationship between consistent deep knowledge of processes and the quality of the innovative solution. The lack of theoretical knowledge of the process must be supplemented by physical and mathematical modeling, which should be followed by process simulation. This also requires continuous digitization, visualization, informatization and quantification of technological and logistics processes. Process modeling and their quantification ultimately allows a qualified view of the modeled process. It is necessary to reach depth of the process that makes possible to see not only the consequences but also the causes of the problem. Design clearly states the direction: "seeing = knowing"! New perspective - new knowledge is the key to a new solution. For a new view of the system, sometimes it is enough to change the view angle. A logistical approach to technology design, including the design of technical solutions, can be the new desired perspective that brings a qualitatively new innovative solutions level.

2. PRINCIPLES OF LOGISTICS IN DESIGNING TECHNOLOGICAL PROCESSES

The unusual large amount of solved research and innovation tasks (quite unique in our research environment) as well as their unsolicited solutions results motivated me to analyze the reasons for explanation of this phenomenon. The use of another non-standard but more effective methodology and approach to research and innovation may identify the difference between effective and successful projects. The magic lies in the logistical approach to the technological processes design.

I am presenting my specific experience with the application of logistics approach in technology design, including the design of the technical side and the method of monitoring and management. The analysis covers summarized and generalized knowledge, systematically arranged, and assigned to individual principles - postulates of logistics. The assignment is loose and subjective, because the individual conclusions can be assigned to several principles, or upside down several logistics principles are used to define one conclusion in the design rule form.

2.1. Logistics fundamental No 1: "System approach"

In a systems approach, processes and objects are viewed as a "system", combining set of all elements (elementary processes) and the connections between them and their environment. Links to other processes (systems) are determined and the process management goal is defined. The properties of elements and connections and their synergistic effect are defined and used to achieve the goal. Systematic decision-making is applied, which simultaneously evaluates information from several sources. Optimal result forms the base among global measures. The system approach is manifested by the problem-solving methodology steps: decomposition - analysis - goal - synthesis.

In general, any processes (elements and links of the system) have four basic characteristics: quality, quantity, time, and position. According to the change of parameters, all processes taking place at all levels of any system can be divided into three basic groups:

- **transformation** process changing quality, quantity, and time period,

- **transmission** transport, changing the position in time,
- **accumulation** storage, where only process time attribute is changed.

Transformation (processing and assembly) represents a key technological operation. The subject of transformation management is to ensure the planned (programmed) process of transformation beginning at inputs up to planned outputs. Transformation is the only process, achieving added value, therefore it must be considered as the key priority operation. **Transmission** (transport) and **accumulation** (warehousing) represent logistical services (without added value) operations and provides coordination tasks, management, and flow provisioning. From the system point of view, technological operations represent the elements of the system and the logistics operations the system bonds. The arrangement of the system, the interconnection of elements by bonds is the subject of the system organization.

The above-mentioned theoretical foundations of the systems approach support definition of following conclusions - rules for designing holistic systems:

- The solution basic is the **system decomposition**, followed by **knowledge base** with granularity level, enabling to see the whole system (not only the problem solved) in causal contexts, (reason – issue – result).
- "Design variance (freedom)" is very important. Rigorous solution, focused to given problem only and not to the whole system optimality often leads to isolated separate and pseudo-optimal solutions only.
- The goal of a "good" system design of a technological-logistics system is a symbiosis between a detailed search for the synergy of individual elements and links and a holistic approach, which results in a comprehensive material, technological and system solution.
- Symbiosis and interconnection of material, technological and system solutions is the key to optimal system operation. Knowledge and acceptance of technology physic-chemical conditions is inevitable for right priorities setting for material-transformation but not for logistics-organizational processes.
- Since the optimality of the system is conditioned by the synergy of operation and the use of the optimization potential not only for its parts individually, but especially as a complex, the final result of the system solution will be complex 4E production systems (4E - environmental, energy, economic and efficient).

2.2. Logistics fundamental No 2: "Coordination"

The principle of coordination is essential in logistics in the case, a systemic approach is applied. Because most processes are made up of several elements (processes, equipment, production sections, plants), their local goals need to be aligned with the global goals of the entire system-enterprise. Logistics systems used to have a hierarchical management structure and coordination is needed not only at individual horizontal levels but also vertically.

Within this principle of logistics, we propose to define the following conclusions - rules for designing processes, aggregates, lines as well as complex technological-logistics systems:

- **Elimination of storage needs** and integration of processes, equipment into aggregates and technologies. In terms of inventory optimization would be an ideal approach, leading to the storage tanks free production process, certain variant of Just in Time approach. This might represent a technological-organizational optimum. To achieve such a status in mining engineering is probably not realistic vision. Nevertheless, to a limited extent, to eliminate need for storage facilities is realistic and feasible by harmonizing the productivity and capacities of machinery and equipment. This leads to perfect integration of production operations and processes into a single technological unit, eliminating the need to implement service processes and equipment between them. We can provide the Integrated Heat Unit as an example, in which are integrated assemblies like tank, drying, flue gas dedusting, preheating, calcination, cooling, wind sorting and product removal. Another possibility to eliminate the need for containers is use of transport providing container capabilities.

- **Balancing the volume of stocks in storage tanks** means determining the optimal capacity of storage tanks and determining the optimal level of stocks in them according to the needs of the technological process. For this purpose, it is appropriate to use simulation and balance models of the production process. Supply forms the security feature in the system. On the one hand, stocks tie up funds, on the other hand, they are necessary for the optimal functioning and crisis security of certain technological processes. Their placement is necessary in front of a narrow place of the production flow, or in front of continuous units, for example in front of a rotary kiln and a shaft furnace. Based on total volume of operating stocks in the system, the "quality" of the system design can also be indirectly evaluated.
- Ensuring the efficient and smooth operation of the production process evaluated **requires determination of the production optimal size and transport batch** as well as their harmonization. The mining process is characterized by a continuous-discrete material flow, continuously-discretely operating production processes and, hitherto, a variable size of the production and transport batch. The extraction dose is given by the choice of mining method and the dimensions of the mined block, the transport dose by the capacity of the transport facilities and the mineral treatment is mostly continuous. Batch inconsistencies cause raw material mixing, problems with maintaining production quality, unstable gains and yields, and uneven production equipment load.
- **Flow capacity of storage tanks, machines**, aggregates lead to the technology continuation. If it is not possible to remove all the tanks completely, we should focus on the possibility to streamline the production system by utilizing flow tank with FIFO concept (first in, first out) with a piston flow of material in them. Flow tanks, if they work on the principle of gravity, are simple and are easy to operate and maintain. When designing new complex technologies, it is necessary to struggle verticalize the arrangement of equipment and processes. The gravitational principle of organization and securing flows in the system brings secured functionality, efficiency, reliability and enables the creation of self-organized systems.
- **Minimization, straightness, uniformity, and fluidity** of material flow. The basic criteria for the optimality of a material flow are its length, straightness, uniformity, and fluidity. The location and arrangement of processes and straightness affect the length of the material flow, uniformity and fluidity is affected by the level of its use. All the above properties of the material flow affect its economic. Meeting the requirements for minimization, straightforwardness, uniformity and fluidity, it is possible to reduce investment and operating costs, specifically transport and handling costs. Costs resulting from the reduction of inventories and work in progress, as well as maintenance costs, etc. contribute to improving the economic indicators of whole process.

2.3. Logistics fundamental No 3: "Multi-criteria optimization"

The definition of the **global goal** is given by the optimization criteria. Through its coordination of elements and links in the system, logistics directly or implicitly solves the problem of **multi-criteria optimization.** Pay attention to maximum utilization of equipment capacities, minimization of energy consumption, materials, profit maximization, etc. These criteria can be supportive or conflicting. Logistics tries to influence all these criteria, especially in terms of time and capacity, and thus meet the global optimization goal, which leads to the minimization of total costs, respectively profit maximization. However, it is necessary to realize that it acts similarly within the already proposed technology and within the limitations of this technology.

The principle of **multi-criteria optimization** is a universal principle and applies to any, not only technological and logistics systems. The following starting points, rules, conclusions are therefore valid in any human activity.

- Process optimization is a staged process in terms of time and material. Each stage has its own optimization possibilities and limits. **The primary is technical optimization**, defined by **design stage** (optimal process elements) and the organization stage (optimal process links). **Secondary optimization** is the **operational,** consisting of the **planning stage** (optimal process trajectory) and the **implementation stage** (optimal process flow). Deficiencies and shortages in one stage are difficult and costly to compensate in another stage.
- In each real system, several criteria apply. Since there is no secure method by which we can objectively calculate the optimum with several criteria being valid at the same time. The **criteria need to be applied gradually** in the design according to their priority. When designing complex technological-logistics systems, the priority criteria will be material-technological and only subsequently logistical-organizational criteria are to be applied
- A common design flaw resulting from **incorrect prioritization of criteria** is the preference of a technical solution over the technology requirements. Frequently a technological process requirement adapts to the capabilities of the technical unit instead of adapting the parameters of the technical unit according the technology needs.
- Another common design error is the "forgetting" the validity of physics-chemical laws, or efforts to suppress their influence. Sooner as later, it leads to the **emergence of negative phenomena** in the system. However, if their impact is meaningfully applied, it can not only significantly simplify and streamline the technical and organizational side of the proposal, but also bring a qualitatively new level of the whole solution. This will have a positive effect, especially in the operation of given system.
- Currently, the dominant criteria in the proposal are environmental, energy and subsequently economic criteria. The **technological-technical and logistical criteria are assumed to be met**, resp. they are treated only as restrictive conditions.

2.4. Logistics fundamental No 4: "Planning"

The task of logistics is the coordination of flows and links in the system so that the system produces the right product, in the right quantity, time, quality ... To do this, logistics can utilize one tool only - a plan, which defines the time sequence system. Logistics uses the principles of forecasting, goals planning and programming of the course of individual elementary processes. **Logistic supports achievement of best possible economic parameters** of the system operation when material constraints are met.

Among the design rules, derived from previous practical experience, the following can be included in the logistics "Coordination" principle:

- When designing systems, and in particular their control and management methods, it is necessary to be aware of management and logistics **philosophies of the diversity**. While the basis for management is the fault existence (actual in feedback planning and assumed in advance), logistics must plan without it. By emphasizing the course of elementary processes coordination according to a predetermined plan, logistics prevents the occurrence of failures. This is the logistics' competitive advantage. It can only be used if the system is properly designed and takes this into account.
- From the point of view of logistics, the production process orientation based on the PULL system is generally preferred. **Customer dominance presumes PULL principle**. On the other side the PUSH system emphasizes the overall efficiency of production processes, while the PULL system emphasizes variability and flexibility. The ideal situation is a combination of both approaches with the transfer of dominance according to the market situation.
- At present time, the dominant management systems in production processes forms a combined system, composed of program, forward and feedback management. While program-feedback control prevails in

technological processes, **program-forward management prevails in logistics** processes. Due to the growing competitive pressure and requirements for the quality of production, as well as for the flexibility of the system, it is necessary to emphasize the prediction component sin management. This represents a key reason for preferring logistics and process approach (self-organization, self-regulation), informatization and digitization in designing the way systems are controlled today in production process management.

- Coordination is possible only when based on quality information (time-relevant and objective). To ensure them, it is necessary to widely **utilize the processes IT support** - even before the start of the process, simultaneously with the course of the process, as well as after the process ends.
- In the design of a comprehensive production system**, adequate management approaches** must be used in the new technologies design. The focus represents systemic and process approach at all hierarchical levels of business process management. The design of the monitoring subsystem, the control-command system and the process planning and organization subsystem must be implemented in parallel with the new technology design.

2.5. Logistics fundamental No 5: "Algorithmizing"

The principle of algorithmic thinking uses the principle of **creating program algorithms**, where each branch of the algorithm must be consistently implemented, closed, nothing can be left to chance, unclosed. All decision steps must be objectified and standardized in the algorithms. For logistics, algorithmizing is a prerequisite to achieve the objectivity of decision-making at all hierarchical levels. Proper forming of algorithms is prerequisite for efficiency in repeating processes (like planning), a prerequisite for the accumulation of corporate knowledge base, as well as prerequisite for standardization of work procedures. Even defining the methodology of designing new technologies using the principles of logistics is only the application of the logistics principle of algorithmizing.

"Algorithmizing" principle of logistics can be understood in several forms in the figurative meaning of the word. Some of these forms also include:

- **Standardization.** Since algorithm is a standardized notation of a certain sequence of activities, the use of algorithms brings standardization and objectification. Standardization is a tool for streamlining decision-making processes, which reflects the economic benefits.
- **Count forward**, because the unambiguous notation of algorithms makes it possible to predict impact on process outputs according to input changes.
- **Repeatability** supports **multiple and versatile usability** of algorithms, resp. models written by a standard algorithm. The models created within the design can be used in process control, maintenance, and other phases.
- **Simplicity of design** - algorithmizing forces designers to go to the level of elementary processes. It forces to austerity and elimination of unnecessary operations, not affecting the added value. This is a problem in the design phase, but at the same time it forms a significant simplification in construction, operation, and maintenance.
- **Rationality and smart features** of designs - because of advanced control of processes, it is impossible to be achieved without algorithmizing in design. The advanced internal process control approach is perhaps the most powerful tool in technological logistics and the best capture. At the same time, it is also the most difficult to implement. This approach is process-oriented and ensures that the process takes place in its natural, physics-chemical law form and is governed only by the principles of self-regulation, self-management, and self-organization without the need for external user intervention.

3. CONCLUSION

In recent decades, the industry driving force was the informatics, the introduction of which has improved the efficiency of all areas of production and processing activities. Reserves in this area are already practically exhausted and new space for increasing efficiency is being moved to the area of logistics. This paper presents the directions and rules for designing new technologies by consistent application of the logistics approach. The described structured logistics way to entrance is based on the implementation of many projects results in practice and is multiplied by personal experience. Although the findings are of a general nature, they can bear traces of a subjective view, which, as expected, will provoke professional discussion. Objective knowledge in the article contributes to a more efficient logistics approach in the design of technologies and production systems.

ACKNOWLEDGEMENTS

This research was funded by the Scientific Grant Agency of the Ministry of Education, science, research and sport of the Slovak Republic and the Slovak Academy of Sciences and Cultural and educational grant agency of the Ministry of Education, science, research and sport of the Slovak Republic. The submitted paper is a part of the projects "Research and development of new smart solutions based on the principles of Industry 4.0, logistics, 3D modelling and simulation for streamlining production in the mining and building industry" VEGA 1/0317/19 and the project "Projects of applied research as a means for development of new models of education in the study program of industrial logistics" KEGA 016TUKE-4/2020.

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