Homogeneous production processes and approaches to their management

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The logistics as one of the levels of company management deals with managing and securing flows in chains and networks. Typical chain in production enterprises of extracting and processing raw materials are production processes, the chain of production operations. Production processes in the industry that belong to the class are homogeneous production processes. This article discusses the methodology of creating management systems in terms of their specifics.

The basic characteristic of homogeneous production processes (HPP) is manufacturing one product, respectively narrow assortment of products. HPP has specific characteristics and features, such as continuous material flow, discrete and continuity operations and facilities, notably in terms of heating equipment, long life and high investment costs for the construction, big inertia in terms of management, etc. This group also includes the processes and procedures of raw materials extraction processes, processing of raw materials, metallurgical processes, petrochemical manufacturing, building materials processes, etc. Continuously discrete processes, before modelling, are necessary to be transformed into discrete form, because there is a lot of tools for their modelling in the area of discrete processes. This requires specific approaches for their modelling, management and logistics. The basic management principle applied to such processes is a Feed forward, which can provide theoretical invariance of the controlled process.

Key words: *raw materials, homogenous production process, big inertia, feed forward management, continue discrete processes*

Introduction

The production process is a system of production, transport, handling and storage operations which are involved at a certain production cell in the production of certain goods. Dynamic changes in the production process can be carried out at the time:

- Continuous operations (e.g. work crusher, ball mill, slab heating in the pusher furnace, etc.).
- Discrete operation (transport cars, wagons, etc.).
- Combined with a production continuous and discreet operations (Malindžák et al., 2015; Anisimov, 1978; Wild, 1991).

The extraction and processing of raw materials are characterised from the point of continuity as continue-discrete production processes in terms of material flows as well as character work machinery, equipment and aggregates. The most common system of performing the production process is the production line. The production line is a system of machines, machines, aggregates, arranged in sequence according to the production method, the binding of which provide the means of transport, storage and management. From the standpoint of assortment of production process outputs production processes are one of the following (Malindžák et al., 2015; Malindžák, 1998; Waters, 1991; Zimmermann and Soveregein, 1974):

- homogenous in which the output is one or a narrow product assortment. These types of production processes are typical for production processes of raw materials mining and treating, metallurgical production, production of constructive materials, petrochemistry, etc. (Kardas,Skuza 2017, Vilamovaat et al. 2012, Newman et al. 2013).
- non - homogeneous in which the output is a wide range of products typical for automotive, engineering or electrotechnical production.

Differentiation of the present production processes and their maximum specialisation considerably increased their productivity. This led to the fact that product acquirement is realised at several different interconnected objects, every single one of which is specified for execution of concrete production operations, managed in chains, and are the object of production logistics (Malindžák 1998, Wild 1991, Daughterty et al. 2009).

Specific characteristics of homogeneous production processes

Homogeneous production processes contain a great range of peculiarities which enable their characterisation as a separate class of management objects. Their characteristics are as follows:

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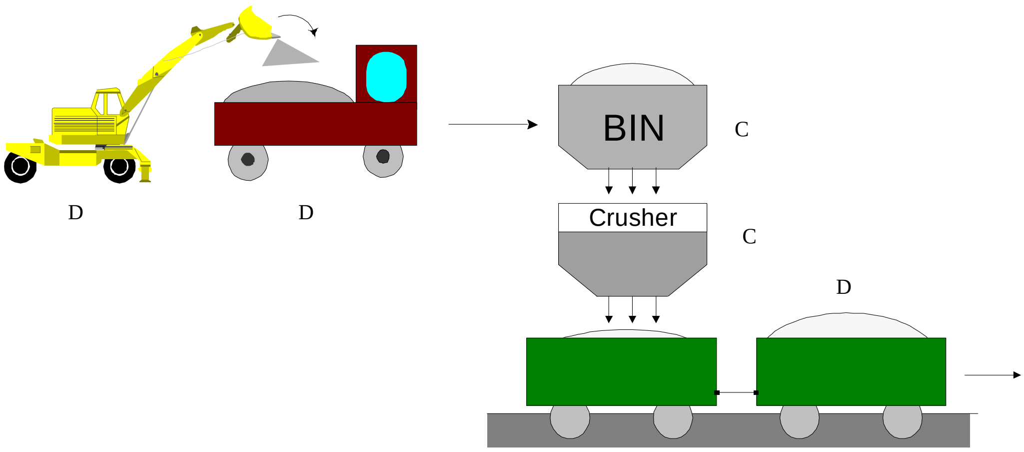
1. Their output is one or a narrow assortment of products, e.g. plates, oils, or coal of different quality.

2. High performance and production productivity Aggregates usually working in uninterrupted regime; idle time is not allowed. The productivity increases with increasing the performance of individual aggregates, because participation of operating personnel increases more slowly than production volumes. It is therefore practical to construct highest performance equipment possible. Savings of relatively small percentage of energy or raw materials costs results, in absolute value, in savings of several million. Efforts to manage them towards the global optimum point are therefore important.

3. The high price of construction-investment. High investment costs are required to construct a blast furnace, plate cold mill or to open a mine. Therefore, when projecting and constructing, the technological conditions are projected at the borderline of an optimum point because this equipment will operate for dozens of years. During the time utilisation of technology, the modernisation that is connected with new scientific and technical knowledge that appears after construction take place. Even the elements themselves (machines, equipment and aggregates) become outdated and their performance, products quality parameters, times of treatment and reliability change (Stojanovič, 2013).

4. They are processes with a changing structure. From the standpoint of system theory, they are systems that consist of a framework through which a flow of products and materials which creates links moves. However, this framework is not necessarily fixed. For example, some vehicles or wagons can be another in the same structure of the mining production process. The system has different characteristics with elements in a different position (for example when a vehicle is by the excavator or by the container, as in Figure 1). This makes their modelling and search for the optimum operation regime complicated.



D-discrete elements, C-continuosly element

Fig. 1. Example of continuously -discrete homogeneous production process (Malindžák et al., 2015).

5. Continuous and discrete equipment. Another difference resides in the fact that equipment which carries out individual production operations can operate continuously or discretely. Figure 1 shows a continuous - discrete production process. Shovel loader at opencast mining is a discrete element of equipment, it works with a certain batch of material respectively (in tons or cubic meters). Vehicles and wagons are discrete elements of equipment which have their own bearing capacity - batch. However, these batches of the shovel loader, vehicle and wagon are different. When managing these processes, it is necessary to know how to model them. They must, therefore, be transformed from the continuous - discrete form into a discrete dynamic event system (Strakoš, 2012; Rosova et al., 2014).

6. Continuous and discrete material flows. Material flow changes from the continuous one (steel in a converter or a crystallizer container of equipment for continuous steel casting respectively) to the discrete one and vice versa. (Vehicles transport raw materials to the crusher container which operates continuously) It is therefore inevitable to define the unit of material flow, e.g. 1 cubic meter or 1 ton respectively and to calculate the performance of continuous and discrete equipment into this material flow unit. This also unifies the batch of material (Strakoš, 2012; Rosova et al., 2014).

7. The tree structure of production processes from roots to maples. Homogeneous production processes are of typical tree structure from roots through trunk and branches up to the leaves. For example:

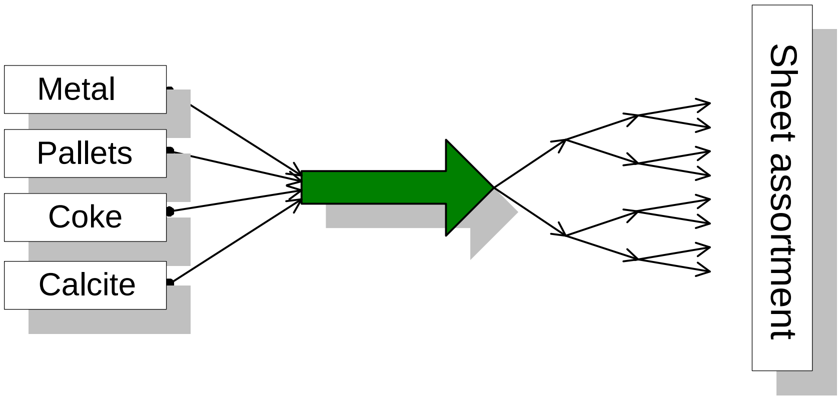


Fig. 2. Tree structure of a homogeneous production process (Malindžák1998)

Iron is produced from iron ore, pellets, coke and calcite. Then, steel is made from it by adding iron scrap, from steel slabs are made metal coils of a black plate which are branched through separation lines and cold mill into numerous kinds of plates of different sizes and quality, but they always remain plates (Fig. 2). Similarly in petrochemistry, different kinds of fuel, oils or asphalt's are produced from petroleum. An opposite structure has assembly production in mechanical engineering and electrical industry.

8. The waste product is not necessarily a waste product. Results of production processes, i.e. products, are often not in accordance with the planned parameters (plate is of different consistency, structure or thickness, the ore is of different composition, coal contains more sulphur, etc.) but are not really waste products. They can be sold at lower prices in a different class of quality, size, etc. If an engineering company produces a foul gear toothed wheel it definitely is a waste product.

Approaches to modelling, logistics and management

These characteristics make modelling and management of homogeneous production processes complicated. They need to be transformed into discrete processes because there does not exist any management theory for such processes presently (Malindžák 1998, Anisimov 1978).

Note: Homogenous production processes and discrete queuing systems have plenty in common (fronts or stochastic characteristics), but there are also numerous dissimilarities and it is therefore not possible to mechanically apply approaches from discrete queuing systems, operation analysis, simulation and discrete systems management.

a) Application of input - output standpoint. If an individual equipment and operations in any production process are viewed from the input - output standpoint, it is possible to consider every production process as discrete one, i.e. equipment is to be imagined as a "black box". External parameters, i.e. operation time, the start of operation, finish of operation, etc. are interesting for the logistic.

b) Discretization of continuously operating equipment. Operation of continuously operating equipment such as crushers, blast furnaces, transport conveyor belts, etc. is made discrete by operational time in which they treat material flow unit, e.g. 1 ton.
For example, The performance of a jaw crusher is 30t/hr, i.e. it treats 1 ton in 120 seconds. This way, the performance of all continuously operating equipment in the production process has to be calculated.

c) Production processes with changing, dynamic structure are transformed into processes with fixed structure by considering the moving elements (vehicles, wagons, etc.) as a static structure. Transport time of a certain number of material flow units which are transported by these elements is then the time of operation duration. (Time is calculated from the means of transport speed, transport distance and bearing capacity.) This way a continuous - discrete production process with changing structure is transformed into a discrete production process with a fixed structure.

d) The great inertia of homogeneous processes. Design of the basic structure of management system structure has to respect great inertia of a homogenous production process. Inertia is great in two ways:

- Large production time, for example, in metallurgical production from sinter production, through the manufacture of iron to the production of an automotive sheet is 3-4 weeks (τ_z).
- Inertia -response to management action will take effect on output products for a few days, weeks (τ_n).

The philosophy of feedback management as the basic philosophy is therefore not appropriate for homogeneous production processes. Feedback management is not capable of ensuring the invariability of a homogenous production process output.

Feedback management with negative feedback has, however, the global sensibility, i.e. if a breakdown occurs in any element of production process management system or in the production process itself, it shows at the output end at all times and management works in its counter-direction.

Let us investigate the second basic way of management - feed-forward management (compensation management).

MSM - management system model
MPP - model of production process
PP - production process
PM - operative planning model
P - comparator
z - vector of breakdown, inputs in PP
w_z - the objectives of the PP from PM
u - vector of decision making
y - vector of outputs
τ_z - transmission time of the break time to output
$\tau_u \tau_u$ - decision-making time
τ_e - time for comparison
τ_n - decision realisation
τ_m - simulation time of the outputs y^*
e - aberration

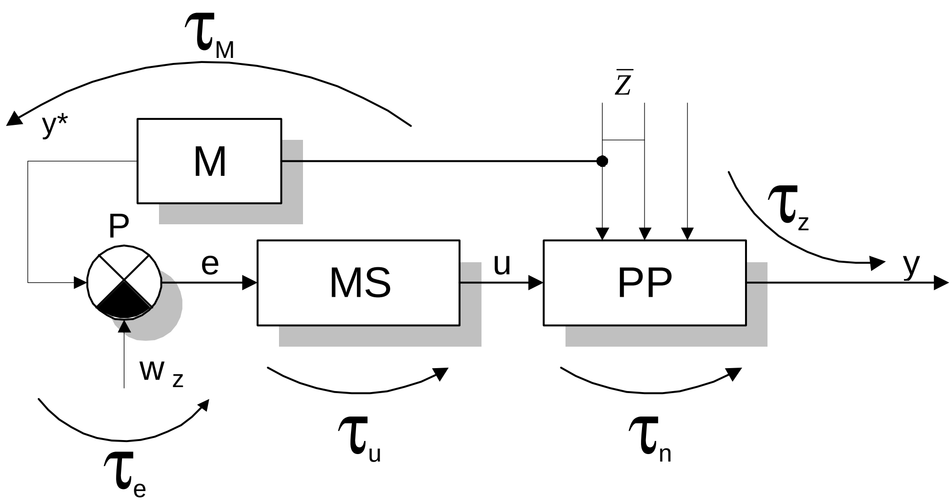


Fig. 3. Principle of feed forward management (Malindžák, 1998)

Figure 3 shows a block diagram of the principle of the feed-forward management as the main principle of logistic and management. For successful implementation of the management and logistic system, on the feed forward principle, is need to create three types of models:

- PM - planning models to define the goals and behaviour of *PP* as models for the preparation of the Annual Implementation Plan for production and trade, capacity production scheduling recurring over a period of a year, month, week, scheduling the production lines, machines, workstations, operating distribution plans
- MPP - management model of production and logistics processes on which simulation is carried out by changes in input variables (cancellation of orders, rejection of contracts, change in volume orders, new customers in the distribution system, new machines in production), network models for expressing critical path in project management, simulated plan of production and distribution through the queuing systems, simulation models, Gantt charts showing the progress of the process and so on.
- MSM - models for decision support (such as the curve of a product life, the S-curve of dispatching management, forecasting models in the strategic planning and annual planning etc.).

Selections of the most important breakdowns which affect the production process are at the same time input to the model of production process MPP. Value y^* as a result of the breakdown effect on the model *MPP* is an image of how the breakdown shows at the output *y* after τ_z time.

The value of y^* is compared to the planned values of *Wz* and an aberration *e* is calculated, based on which the management system develops the "*u*" decision which affects to the production process in counter-direction to the breakdown effect(Malindžák et al.2015, Malindžák 1998). In this management diagram, a principle of double channelling is fulfilled, which is a necessary condition of accomplishing a complete invariability. This system of management is very speedy in many cases. Principal possibility of developing an invariant system resides in the fact that the inertia of a canal in which the breakdown occurs $z \rightarrow PP \rightarrow y$, can be significantly higher than of the canal

$$Z \rightarrow MPP \rightarrow y^* \rightarrow P \rightarrow e \rightarrow MSM \rightarrow u \rightarrow PP \rightarrow y,$$

i.e. the following formula must be valid:

$$\tau_z \leq \tau_M + \tau_e + \tau_u + \tau_n$$

The basic problem is the development of a speedy *MPP* model. Great attention is therefore dedicated to the discretization of homogeneous production processes because well - designed methods for discrete production processes modelling such as the following are used for their modelling:

- theory of discrete queuing system,
- simulation principles,
- theory of graphs,
- heuristic approaches,
- linear and dynamic programming,
- statistical methods,
- and other methods of the system analysis and synthesis(Malindžák et al. 2013, Lenort et al. 2012, Newman et al. 2013).

A disadvantage of feed-forward management resides in its local sensibility, i.e. the management system designed by the feed-forward principle of feed-forward management is sensible only of breakdowns located through the M model. Logically, the global sensibility of the feed-forward management system and double channelling of the feed-forward management system within a single management system is offered for utilisation (Malindžák 1998). One of the ways to design this structure is in Figure 4.

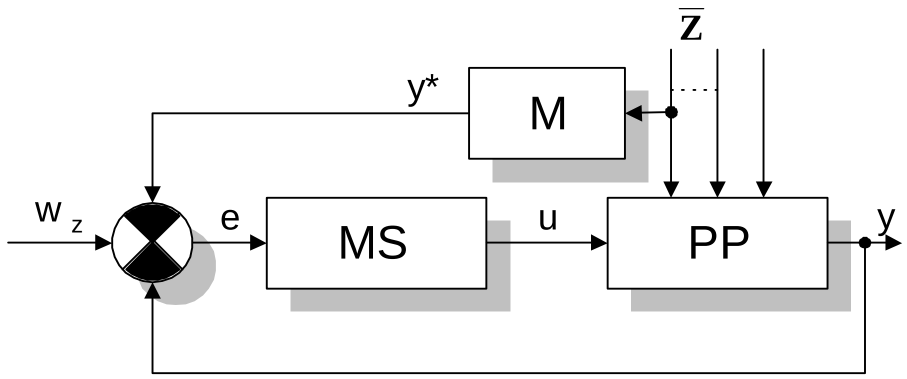


Fig. 4. Combined management system (Malindžák et al., 2015).

e) <u>Logistics triads and cascade principle.</u> The system approach is one of the basic principles in logistics. The logistic chain has to be created from at least three elements. Generally, logistic chains are created from more than three elements. A great number of elements got the bigger chance to find better optimum and effect from overall optimisation is higher. From the division of work in the chain, on design, realisation and management of the flows in the chain, we can decompose the chain to logistic triads, relatively individual researching.

Logistic chain is created from the triad on the cascade principle, i.e., that output OP_{N-1} activity (element) from triad N-1 is input element in triad IP_N, and output element from triad N is input element in triad N+1.

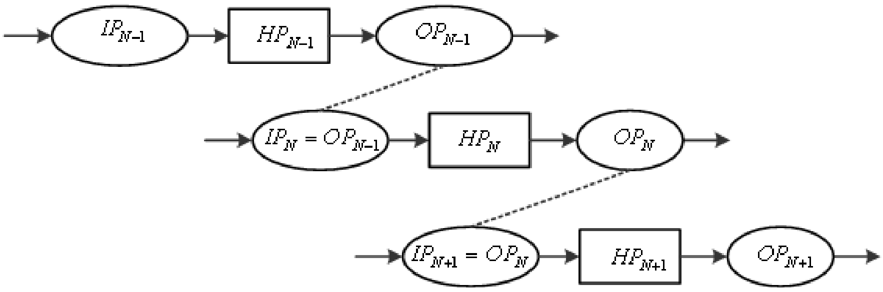


Fig. 5. The cascade principle for design of logistic chain system (Malindžák et al., 2015).

f) The hierarchic management system - principle of coordination and overall coordination

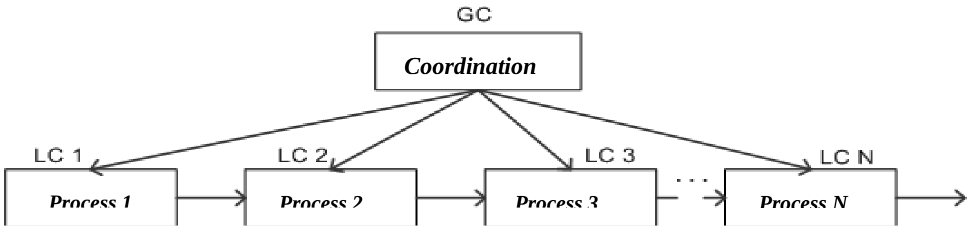


Fig. 6. The principle of coordination of logistic chain (Malindžák et al., 2015).

The principle of hierarchic management of logistic chain:

1. The chain is created by realisation flow through the individual element. This coordination has some criterion:

- minimum realisation time,
- minimum cost,
- minimum storing products, goods, information, finance etc., it is performed as a plan (production, maintenance, transport, etc.).

The executive capacity plan is prepared on the level of chain (chain of company, chain of distribution companies, chain of activities, chain of operations). Operative plan and schedule are prepared on the local element and to fulfil the plans of the coordination level (Shim, Siegel 2009, Zimon 2015, Malindžák, Zimon 2014, Straka et al. 2014, Newman et al. 2013)

2. The scheme principle is that local optimality criteria of processes $\overline{LC}_N$ have to respect (support) the overall- criteria of optimality GC.

g) The overall optimisation. The overall optimisation of the chain is the main sense, targets of logistic and results from its substance. The overall optimisation is based on the idea, that local optimisation of elements-activities are chains which have to be subordinated to the main overall criterion of the chains. From this point, the system of overall optimisation is hierarchic optimisation task. The overall criterion is, i.e. minimal cost, profit maximisation, and the subordinated criterion is, e.g. maximum utilisation of machine capacity, optimal product sequence, minimal production time, etc.
Very often, overall optimisation task is solved by multi-criteria optimisation (Straka et al. 2014, Mohammadi 2015).

Discussion of results

Production processes in the acquisition and processing of raw materials belong to the group of homogeneous production and from continuity of material flow and production activities of devices has continuous, discrete character. These types of manufacturing processes have in terms of management and logistics the following characteristics:

- assortment- one or a narrow range of products,
- high performance and productivity,
- high price of construction-investment,
- they are processes with a changing structure,

- continuous and discrete equipment,
- continuous and discrete material flows,
- tree structure of production processes from roots to maples,
- waste product is not necessarily a waste product.

Production processes of this type are characterised by high inertia in terms of production but also management. Establishing an effective management system requires a fundamental principle applied a forward management system. As is apparent from Fig. 3, three types of models need to be designed for its application: The MPP-model production process, MP-planning model for the appropriate level of management and management and decision support model- MSM. But the priority is on the fast MPP model, without which the forward management system will not work. The first step in the creation of the production process model is discretisation-transformation of a continuous-discrete process to discrete process, which would be easier to model. The paper describes procedures of discretisation. The following should be applied for the design of logistics system and management:

- feed forward or combined management system,
- decomposition of modelling process in decision triads,
- application of the cascades principle of cascades,
- hierarchic management system, based on coordination,
- a heuristic approach is of the most common for developing planning models and the management,
- for modelling production processes, operational analysis models and simulation approach,
- the overall chain optimisation, by applying multi-criteria optimisation.

Conclusion

The article describes the specifics of homogeneous production processes in terms of logistics and management, which are typical for processing of raw materials. The priority is aimed to the approaches and principles for solving problems such as big inertia, continuously -discrete equipment and material flows, the management of large chain.

The article has a theoretical and methodological nature. The paper describes the specifics of homogeneous production processes and procedures for such access to their modelling and management. Production process is understood as a chain of production, transport, storage and management operations, e.g. logistics chain, so in addition to the basic principles of cybernetics and management, it is necessary to apply the principles of logistics, such as the principle of elementary information processes, decision making triads principle, cascade principle, coordination and overall optimization. The basis for the management of these processes, however, is feed forward management system application that requires models of manufacturing processes -MPP. To create these models, it needs that continuous -discrete production processes transform to discrete form. The article describes the approach to discretisation. This methodology has been proven in dozens of projects for industrial enterprises in Slovakia (Siderit N. Slaná s.r.o., USS Košice s.r.o., SMZ Jelšava a.s., Rosemberg Slovakia s.r.o., Chemosvit fólie a.s., Svit, etc.).

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