

Logistic Optimization of the Production Centre

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Abstract—Today's entrepreneur environment is extremely turbulent and new methods, possibilities and ways are being searched for in all its areas in order to optimize each available process. Optimization is carried out mainly and, we can say, exclusively in order to achieve the maximal output and production. At the same time we have to minimise the input data, losses, human resources, etc. Optimization must be carried out at all levels taking into account either internal or external processes. This all ought to consider the wide range of influencing factors which must be identified in advance and subsequently evaluated from the point of view of weight of their influence. It is very important to implement the system approach to solve this problem. This approach analyses the general model of the business system on the basis of which the company with its own manufacturing process and commercial activities functions. The commercial activities are then oriented towards the acquisition of charge materials as well as the sale of ready products. This model is often marked as the commercial-manufacturing centre. If information systems (IS) along with information and communication technologies (ICT) are added to the presented model in order to support all its activities, the so-called e-business system appears, which can at present be treated as the most general model to realise a defined business activity. Commercial-manufacturing centres are characterized by a need to optimize and rationalise manufacturing processes. To optimize it is possible to implement a wide range of methods and procedures which can be either used for either specific goals or creating more universal equations. The paper highlights the problem of optimization, first of all, manufacturing processes of the commercial-manufacturing centre based on the principles of lean company and lean manufacturing with the integrated system of the so-called permanent simulations. In addition, as a practical case the logistic modelling problem of the production centre consisting of machines which carry out dedicated operations on defined objects is presented. The optimization criterion for the timescale of servicing objects in the production process is given. The method shown hereby emphasises the state of the decision process, the value of the state, functions of generating states and heuristic algorithms for generating trajectories of states.

Keywords—logistic centre; optimization; lean company; modelling; simulation software; heuristic algorithms; decision process

I. INTRODUCTION

Growing competition, the aftermath of the economic crisis, growing saturation of the market, growing expectations and demands of customers, etc., lead to a need to change approaches towards managing and organisation of all types of companies. As an example shown in [12], not relatively long ago it was a common practice to realise supplies to not so geographically remote localities. Moreover, only local competitors were faced and local problems solved. Today it is possible and, we should admit, it is necessary to manage long distance deliveries and face global competition. Market opportunities emerge much faster than in the not so distant past. It is necessary to identify them properly at the right time and make use of them. One of the accepted ways to secure the development of the company are innovation activities which must be implemented within all other business activities. If we take into account the model of the general company oriented towards manufacturing and selling ready products (the so-called commercial-manufacturing centre), we can then deal with optimization of its processes oriented towards commercial activities (acquisition of new charge materials and selling ready products) and manufacturing procedures. Manufacturing processes are the key issue in commercial-manufacturing centres. On the other hand, optimization of manufacturing logistics as a complex of all direct and indirect activities plays a more and more important role in its relation with manufactured goods, charges, implemented technologies and production organisation [7]. Manufacturing costs are usually a decisive part of all costs in more cases and this leads to the conclusion that analysing these problems intensively is unavoidable for most manufacturing companies. Commercial-manufacturing centres can be realised as manufacturing branches of the main company in different and geographically remote localities. The general scheme of managing such a centre is shown in Fig. 1. These centres usually emerge in the so-called industrial zones and, from the point of their organisation, they can be based on the lean company concept and lean manufacturing. The paper focuses on presenting the main rules and principles used for realisation commercial-manufacturing centres as a trend of today's and tomorrow's times and its direct relation with the logistic concept of the lean

company respectively lean manufacturing. To optimize lean manufacturing of any commercial-manufacturing centre it is possible to implement a wide range of dedicated methods and devices, which are also emphasised in the paper. As a practical case, the paper highlights the logistic modelling problem of the production centre consisting of machines which carry out dedicated operations on defined objects.

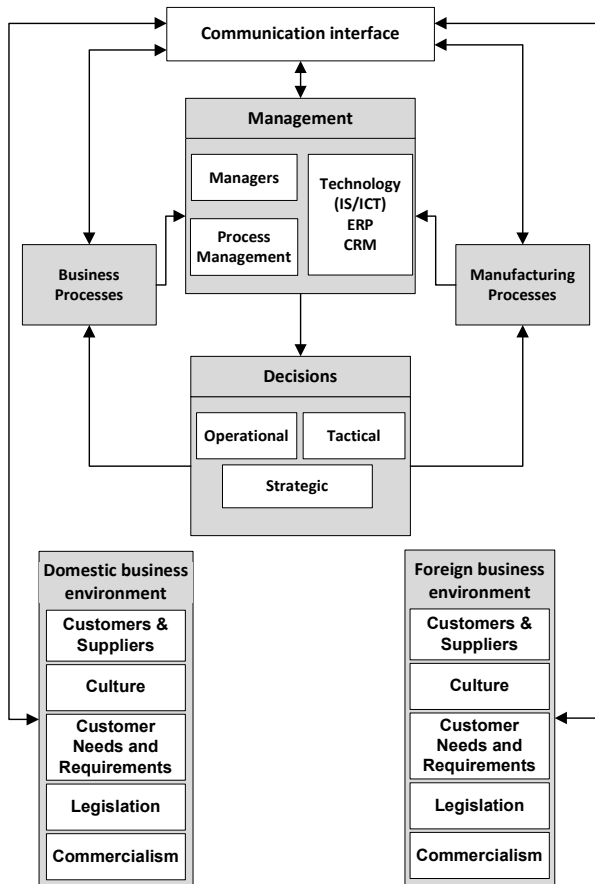


Fig. 1. The scheme of the general commercial-manufacturing centre. Source: adapted from [20]

II. LEAN COMPANY AND LEAN PRODUCTION

Lean company and lean production do not represent any specified method of manufacturing but rather managerial philosophy. As known, it concerns the methodological approach developed by Toyota after World War II as Toyota Production System (TPS). At present, it has been proven a lot of times that introducing lean manufacturing results in real conveniences. The examples of companies which successfully introduced the lean manufacturing concept are Škoda auto, a.s., Gates Hydraulics s.r.o., Hyundai, Shimano and many others. Lean manufacturing focuses on typical orientation towards customers and process management, elimination of losses, securing the fluent manufacturing process and material flow as well as information dedicated for manufacturing and its management. It also makes use of the move principle and the constant process of development [26], [15]. We can generalise the above taking into account that the basic foundation for implementation of the lean company model and especially lean manufacturing is the proper identification of all ways of

creating losses. However, this does not concern only material losses but also time and human potential losses, etc. The ways of creating losses and their causes are presented in Table. I.

TABLE I. WASTE- ITS CAUSES, SYMPTOMS AND CONSEQUENCES

The type of loss	Typical causes, symptoms and effects
Waiting	Waiting for material, semi-products, machine defects, waiting for examination, waiting for quality control inspection, waiting for the subsequent task
Excessive state of material	Wrong planning, low quality, lack of transparency, hiding problems
Excessive transport and manipulation	Wrong layout of the company, wrong material disposition, inter-operation stores
Manufacturing wrong parts	Extra wages, material and energy, usage, extra control inspection, place for repairs
Overproduction	Wrong planning, economic losses, lack of transparency, hiding problems
Unnecessary processes	Unnecessary operations, wrong construction, over-manipulating, unnecessary machine work
Excessive moves	Badly organised work place, badly planned processes, wrong layout
Unused human potential	Labour force is the most important and costly source, the above kinds of losses lead to losses in human potential

Source: adapted from [22]

We come to the conclusion on the basis of the above that the main goal of the lean company and manufacturing is to increase quality, decrease costs and shorten the production cycle. The growing level of the quality of the production process means decreasing the number of errors, repairs and discards. The use of company's sources is lower then and it results in lower total costs of manufacturing. The production process begins with human resources, installations and input materials and finishes in the form of ready products. The productivity grows if we can generate more products at the end of the manufacturing process from the same amount of input materials or if less charge material is required to produce the same number of ready products. The manufacturing cycle is the time which passes between accepting input materials in the company and receiving the payment for ready products manufactured from these input materials. Shortening this interval means the ability to manufacture more products at the same time, shorter return on investments and faster reaction to customers' needs.

III. RECENT METHODS OF PRODUCTION PROCESSES OPTIMIZATION

Confirm as emphasised in Part 1, it is possible to say that each manufacturing process ought to result in the products which meet the quality requirements. Even the big output should not influence the quality. Customers want the cheapest possible products, however, the producer wants the highest profit at the optimal production costs with no losses if possible. Optimization is understood as a broad spectrum of various manufacturing factors which form one consistent body. If it is

properly implemented, the maximal effectivity is achieved and treated as optimization which is perceived differently depending on the production branch, public philosophy or market environment. To achieve the demanded level of optimization, it is necessary to put a lot of attention to fulfilling the goals such as liquidate defects and losses within the manufacturing process, predict defects and deviations, keep the continuity of the manufacturing process, decrease the percentage of waste material, find the origins of problems and implement the right means to avoid them, optimize production costs and decrease losses, optimize the use of human potential, shorten the production line, reduce manufacturing and storing spaces and spaces devoted to administering activities, reduce the excessive state of stores and increase the knowledge base. Optimization of manufacturing processes must also be understood as a part of complex system optimization of management and logistics in relation with the scheme in Fig. 1. In accordance with today's understanding of commercial-manufacturing centres it is also necessary to optimize commercial processes which are realised in e-business and e-commerce environment and which also require new approaches and offers new opportunities to meet customers' needs [5].

At present, it is known that the complex logistics system is the key for the enterprise to utilise sufficiently all production capacity, to reduce the cost, to increase the effectiveness and improve the competitive capacity of product in the market [25]. Optimization uses a wide range of methods and approaches. The basic assumption requires creating adequate models [4] with the use for example process oriented approach [17], [23], value oriented approach [18], [24] multi-agent approach [27], [3], [10], [28], neural network [9], discrete or continuous Petri-nets approach [13], fuzzy-multi objective approach [6] or heuristic algorithms which are responsible for meeting the set criterion [2], business intelligence tools [20], genetic algorithms [11] or [16] and other mathematical and special approaches presented, for example, in [8]. In many cases it is advisable and very effective to use combination of different methods and approaches. The reason is quite simple. The general logistics system is usually too complex to be modelled mathematically, or the models are overly computation intensive to be applied in real-time environment. As an example of a combination of methods can be presented an application of genetic algorithm for logistics based on multi-agent system which is described in detail in [19]. In this context, it is clear that the use of genetic algorithms is becoming more common. But it is still generally true that mathematical models are the starting point for solving a number of practical examples, and we cannot do optimization of system without them.

Models and their mathematical interpretation form the basis for potential simulation procedures which become a very effective tool for optimization of a wide range of manufacturing, commercial and other systems. One of the most advanced and, at the same time, the least appearing management methods in information systems is the concept of permanent simulation and optimization of the manufacturing system (Fig. 2). Here, the control layer represents control activities primarily directed at real activities. Input values, which are used as comparative values throughout the simulation process, are included in the timetable. Effective

regulation actions are realised on the basis of their evaluation in the simulation layer. It is possible to carry out simulations based on all three models (process oriented, value oriented, multi-agent-oriented, Petri nets, etc.) which can help managers test some assumptions. They can be a decisive support while making the proper decision. However, simulators are as good as the assumptions and the project used for preparing the required model. This approach enables the operator of the manufacturing system to evaluate online all important manufacturing and associating activities which as a result leads to formulating the adequate managerial decision.

The control system with implementation of the permanent simulation layer can be used for planning and time-scaling production, monitoring, evidencing and dispatcher's decision making. Dynamic planning of the manufacturing process enables direct control of the flow of materials throughout the manufacturing process with minimum expectations for collecting data.

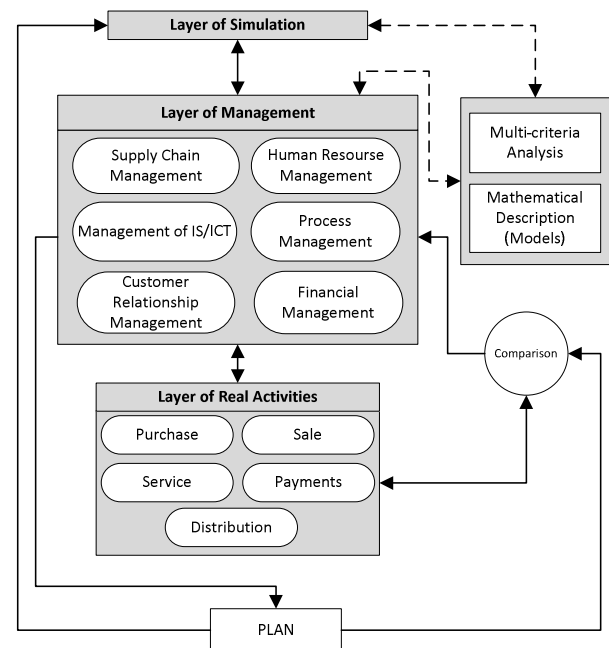


Fig. 2. Integration of simulation into the management system. Source: adapted from [21]

Then, the information system delivers data concerning the current state and conflict spots in the manufacturing system, informs about delays and their aftermath of realising the production plan. Moreover, it secures manufacturing automatically with necessary input data and capacities at the optional time interval. It is also possible to control and follow input, output and inter-operation activities, react to changes within and in the close neighbourhood of the manufacturing process and, finally, solve the machine and space organisation of all resources used during the manufacturing process. Apart from detailed planning and following the flow of material during the production process, it also delivers the necessary cost and economic evaluation with the direct feedback on accountancy operations and not completed manufacturing and moves of resources. Some chosen measurable and general

effects of the control system with integrated permanent simulation are presented in Table. II.

TABLE II. MEASURABLE AND OTHER BENEFITS OF CONTINUOUS SIMULATION SYSTEM

Measurable benefits	Other benefits
Increasing productivity	Specification of empty or missing capacities
Increasing production capacities and other processes	Better planning of human resources
Decreasing wage costs	Better work organisation
Decreasing state of resources and work in progress	Increasing work safety
Decreasing storing areas	Higher work transparency
Saving normative work hours and their costs	Decreasing re-work
Decreasing inadequate production and excessive work	Securing the right move, the right supplies at the right time, at the right amount
Increasing the use of machines, decreasing the time for adjusting	Higher manufacturing flexibility

Source: own

The foundation for realisation of the dedicated simulation process is creating software products which are in most cases created for specific purposes of a certain company, in our case it is the commercial-manufacturing centre. Simulation software must be built in the way which meets the principles of the architecture of management and organizational activities to be simulated. These simulators enable us to use a wide range of mathematical approaches presented above. The software simulators can be used in different areas. One of the practical examples can be found, for example, in [14]. In this paper a practical case can be illustrated by the use of heuristic algorithms.

IV. LOGISTIC MODELLING PROBLEM OF THE PRODUCTION CENTRE

Let us assume that the production centre consisting of M machines is given: $A_m, m = 1, \dots, M$. There are N objects which are to be manufactured in this centre: $P_n, n = 1, \dots, N$. Each object requires one operation which is carried out in each machine. The times of performing each operation in the m -th machine for the n -th object are given as $c_{m,n}$. The order of performing an operation for the n -th object and a machine in which this operation is to be carried out are optional. The problem consists of determining the timescale of operations which lets us produce all objects in the shortest possible time.

Let $t_{m,n}$ be the moment of completing the service operation of the n -th object in the m -th machine. Moreover, let us mark the work timescale of the m -th machine as $H_m, m = 1, \dots, M$. The timescale H_m determines the moment of completing servicing of all objects in the m -th machine. Such a timescale takes the following form (1):

$$H_m = \langle t_{1,m}; t_{n,m}; t_{N,m} \rangle \quad (1)$$

Analogously, it is possible to determine the service timescale $H_n, n = 1, \dots, N$ for servicing the n -th object in all machines. Such a timescale takes the following form (2):

$$H_n = \langle t_{n,1}; t_{n,m}; t_{n,M} \rangle \quad (2)$$

To solve the discussed problem it is necessary to determine $M \cdot N$ moments $t_{m,n}$. The optimization criterion for the timescale of servicing objects in the production centre takes the following form (3):

$$Q = \max_{1 \leq m \leq M} \max_{1 \leq n \leq N} t_{m,n} \rightarrow \min \quad (3)$$

The problem formulated above can be solved by means of the multi-stage programming method [1]. This method requires defining:

- i. the state of the decision process;
- ii. the value of the state;
- iii. functions of generating states;
- iv. heuristic algorithms for generating trajectories of states.

The definitions are given adequately below:

A. Definition 1: The state of the decision process

The state of the decision process is the matrix X with M columns and N rows. The columns represent machines and the rows represent objects (4):

$$X = [x_{m,n}], \quad m = 1, \dots, M, \quad n = 1, \dots, N \quad (4)$$

The elements of the above matrix are defined as follows:

$$x_{m,n} = t_{m,n} \quad \text{if the } n\text{-th object was serviced in the } m\text{-th machine,}$$

$$x_{m,n} = 0 \quad \text{otherwise.}$$

The initial state (of stage 0) X^0 is shown by the matrix in which the elements equal zero. The allowable final state $X^E, E = M \cdot N$ is a matrix where all elements have a value above zero. The final state is not known and must be determined by means of multi-stage programming.

B. Definition 2: The value of the state

The value of the state is the scalar V which is determined on the basis of the following formula (5):

$$V = \max_{1 \leq m \leq M} \max_{1 \leq n \leq N} x_{m,n} \quad (5)$$

The value V^0 of the initial state V^0 equals zero, however, the value of the final state X^E is the realisation time of the allowable timescale for carrying out all operations. V^{opt} is the lowest value for the optimal state X^{opt} .

To determine the allowable solution X^E there is a need to generate the trajectory of states (6):

$$X^0 \rightarrow X^1 \rightarrow \dots \rightarrow X^{e-1} \rightarrow X^e \rightarrow \dots \rightarrow X^E \quad (6)$$

Let us assume that the state X^{e-1} is given and the next allowable state X^e must be determined.

C. *Definition 3: The function of generating states takes the form (7):*

$$\forall \forall_{m,n} (x_{m,n}^{e-1} = 0) \Rightarrow [X^e = F(X^{e-1}, m, n)] \quad (7)$$

The elements of the matrix X^e are determined as follows (8), (9):

$$x_{i,j}^e = x_{i,j}^{e-1} \quad \text{for } i \neq n \quad \text{and } j \neq m \quad (8)$$

$$x_{i,j}^e = t_{m,n} \quad \text{for } i = n \quad \text{and } j = m \quad (9)$$

The moment $t_{m,n}$ is determined on the basis of the formula (10):

$$t_{m,n} = \max(T_m^{e-1}, Z_n^{e-1}) + c_{m,n} \quad (10)$$

Moreover, from the given state X^{e-1} , we are able to determine the following parameters (11), (12):

$$T_m^{e-1} = \max_{1 \leq i \leq N} x_{i,m}^{e-1} \quad (11)$$

$$Z_n^{e-1} = \max_{1 \leq j \leq N} x_{n,j}^{e-1} \quad (12)$$

D. *Definition 4: Heuristic algorithms for generating trajectories of states consist in determining the m-th aggregate and the n-th object.*

The above definition can be justified by the following examples:

1) The choice of the m-th allowable aggregate which is the first free one in the state X^{e-1} and the choice of the n-th allowable object which can be served as the first one in this aggregate.

2) The choice of the n-th allowable object which is the first free one in the state X^{e-1} and the choice of the m-th allowable aggregate which is the first free one to serve this object.

3) The choice of the n-th allowable object which is the first free one and the choice of the m-th allowable aggregate in the way which allows servicing this object in this machine in the fastest possible way.

V. CONCLUSIONS

The trend of the contemporary times is to organize manufacturing companies in the form of the so-called commercial-manufacturing centres which are located in suburban industrial zones. These centres are created, organized and managed on the basis of the lean company. Such companies are supported by simulation, especially permanent simulations which are realized with the use of the special software implementing various heuristic algorithms. As one of the examples we can propose a sample case of solving the logistic problem by means of mathematical modelling. The case which is thoroughly analysed in the paper is based on the production centre consisting of machines which carry out dedicated operations on defined objects. The goal is formulated in the criterion form and means the need to

minimize the order realization time. The method shown hereby emphasises the state of the decision process, the value of the state, functions of generating states and heuristic algorithms for generating trajectories of states. Finally, it should be noted that in this paper presented model was applied in one enterprise in the Czech Republic and in one in Poland. Currently we collect statistical data that will be evaluated at the end of 2013.

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