Information Modelling of the Manufacturing Centre with the Use of the Heuristic Algorithms

Petr Suchánek, Robert Bucki, Franciszek Marecki and Eva Litavcová

Abstract **—**The paper highlights the problem of mathematical modelling of the manufacturing centre. 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. A logistic modelling problem of the production centre is described in detail. The goal is formulated in the criterion form and means the need to minimize the order making time. Heuristic optimisation plays the vital role aiming at finding the optimal solution to the specified task. 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. Heuristic algorithms are introduced: the heuristic of preference of machines, the heuristic of preference of objects and the evolutional heuristic. The way of mathematical modelling presented in the paper forms the basis for building a computer simulator of the manufacturing logistic system.

Keywords**—**logistic centre, optimization, lean company, modelling, simulation software, heuristic algorithms, decision making 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 [14], 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 [8]. 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.

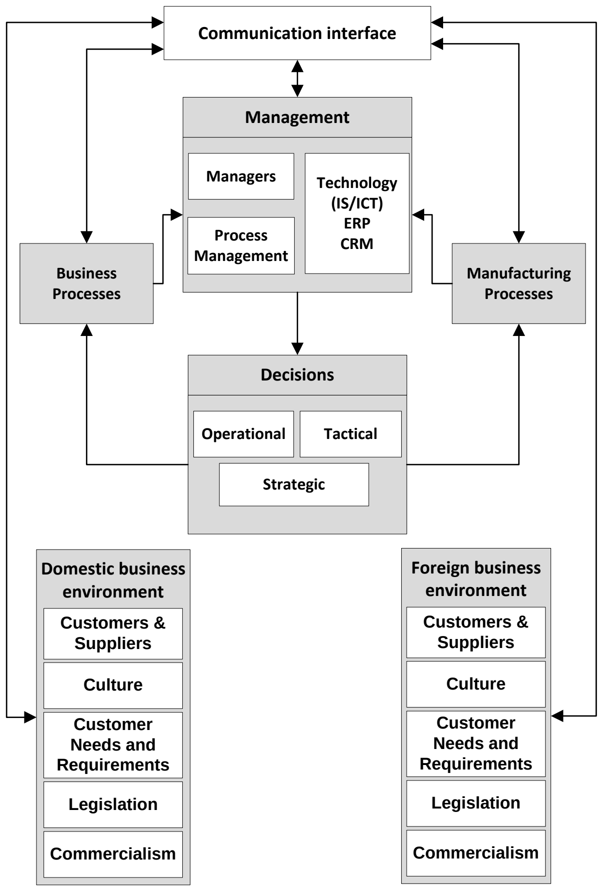


Fig. 1 the scheme of the general commercial-manufacturing centre
Source: adapted from [23]

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.

This paper was supported in part by project “Innovation of study programs at Silesian University in Opava, School of Business Administration in Karviná” Nr. CZ.1.07/2.2.00/28.0017.

Petr Suchánek is from Silesian University in Opava, School of Business Administration in Karviná, Czech Republic (+420596398322, e-mail: suchanek@opf.slu.cz).
Robert Bucki is from Institute of Management and Information Technology in Bielsko-Biała, Bielsko-Biała, Poland (e-mail: rbucki@wsi.edu.pl)
Franciszek Marecki is from Academy of Business, Dąbrowa Górnicza, Poland (e-mail: fmarecki@gmail.com)
Eva Litavcová is from Prešov University in Prešov, Faculty of Management Prešov, Slovakia (e-mail: eva.litavcova@unipo.sk)

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. Additionally, three heuristic algorithms illustrating the possible control of the proposed system are described in detail. Consequently, they form the basis for creating a computer simulator of the discussed logistic system.

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 [28], [17]. 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 Tab. 1.

Tab. 1 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 [24]

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 [6].

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 [27]. Optimization uses a wide range of methods and approaches. The basic assumption requires creating adequate models [5] with the use for example process oriented approach [19], [25], value oriented approach [20], [26] multi-agent approach [29], [4], [12], discrete or continuous Petri-nets approach [15], fuzzy-multi objective approach [7] or heuristic algorithms which are responsible for meeting the set criterion [3], business intelligence tools [22], genetic algorithms [13], [18], and other mathematical and special approaches presented, for example, in [10], [9], [11]. 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 [21]. In this context, it is clear that the use of genetic algorithms is becoming more common.

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).

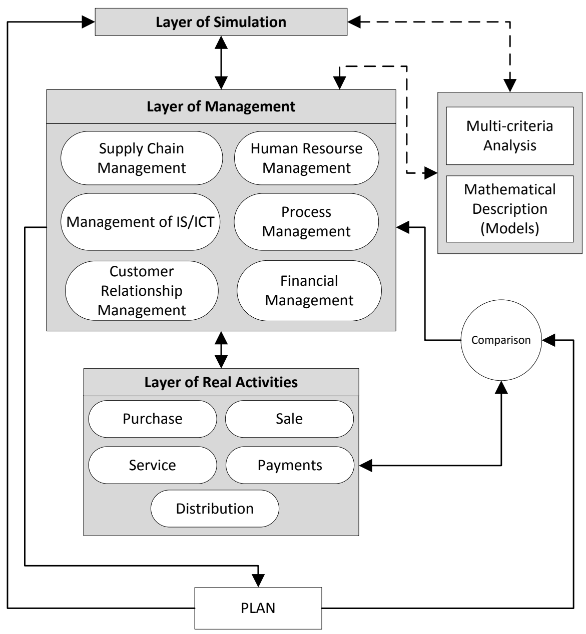


Fig. 2 integration of simulation into the management system
Source: adapted from [23]

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.

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 Tab. 2.

Tab. 2 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 [16]. In this paper a practical case can be illustrated by the use of heuristic algorithms.

IV. Heuristic optimization

The principal advantages of heuristic algorithms are that such algorithms are often conceptually simpler and almost always much cheaper computationally than optimal algorithms. Heuristic optimisation algorithms are artificial intelligence search methods that can be used to find the optimal decisions for designing or managing a wide range of complex systems. As shown in [1], a heuristic is a method that ‘on the basis of experience or judgement seems likely to yield a good solution to the problem but cannot be guaranteed to produce an optimum’. Although over the years there have been some advances in exact optimization, heuristics continue to be very popular in the operational research community and logistics for a number of reasons:

- The computational complexity of many problems means that optimal solutions are unlikely to be found in reasonable time in larger instances.
- Problems may be ill-defined or data imprecise, so that an optimal solution based on estimated data will almost certainly not be optimal for the actual data. In such a situation it is preferable to obtain a robust solution that will be near-optimal over most scenarios.
- The user may require several different solutions to make the final choice, particularly in situations where there are several criteria needed to be balanced using human judgement rather than technical measures.

V. Logistic Modelling Problem of the Production Centre

Let us assume that the production centre consisting of M machines is given: A_m, $m = 1,\ldots,M$. There are N objects which are to be manufactured in this centre: P_n, $n = 1,\ldots,N$. 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, $m = 1,\ldots,M$. 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):

$$H_m = \langle t_{1,m};\, t_{n,m};\, t_{N,m} \rangle \tag{1}$$

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

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

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):

$$Q = \max_{1\le m\le M}\ \max_{1\le n\le N} t_{m,n} \rightarrow \min \tag{3}$$

The problem formulated above can be solved by means of the multi-stage programming method [2]. 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):

$$X = \left[x_{m,n}\right]\ ,\ m = 1,\ldots,M\ ,\ m = 1,\ldots,M \tag{4}$$

The elements of the above matrix are defined as follows:

$x_{m,n} = t_{m,n}$ if the n-th object was serviced in the m-th machine,
$x_{m,n} = 0$ 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):

$$V = \max_{1\le m\le M}\ \max_{1\le n\le N} x_{m,n} \tag{5}$$

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):

$$X^0 \rightarrow X^1 \rightarrow \ldots \rightarrow X^{e-1} \rightarrow X^e \rightarrow \ldots \rightarrow X^E \tag{6}$$

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):

$$\underset{m}{\forall}\ \underset{n}{\forall} \left(x_{m,n}^{e-1} = 0\right) \Rightarrow \left[X^e = F\left(X^{e-1}, m, n\right)\right] \tag{7}$$

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

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

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

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):

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

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

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.

VI. Heuristic algorithms

It is assumed that there are *M* machines A_m, $m = 1,...,M$ and *N* objects ω_n, $n = 1,...,N$. Each object should be served only one time in each machine. The service times $c_{m,n}$ of the object ω_n in the machine A_m are given.

The timescale for servicing all objects in all machines must be determined in order to minimize the time of the service process of objects.

Let us mark the moment of finishing servicing the object ω_n in the machine A_m as $t_{m,n}$.

Solving the problem with the use of the multi-stage programming method it is possible to define the state *X* in the following way (13):

$$X = \left[x_{m,n}\right], \ m = 1,...,M, \ n = 1,...,N \quad (13)$$

where $x_{m,n} = t_{m,n}$ if the object ω_n was serviced in the machine A_m, otherwise $x_{m,n} = 0$.

The solution to the problem can be obtained by means of generating the trajectory of states (14):

$$X^0 \to X^1 \to ... \to X^{e-1} \to X^e \to ... \to X^{M \cdot N} \quad (14)$$

The state X^0 is defined by the matrix *X* whose all elements equal zero. The final state $X^{M \cdot N}$ is a matrix whose all elements have values above zero. The final state represents the allowable solution to the problem.

The function of generating the trajectory of states takes the form (15):

$$\forall_m \forall_n \left(x_{m,n}^{e-1} = 0\right) \Rightarrow \left[X^e = F(X^{e-1}, m, n)\right] \quad (15)$$

Obtaining the optimal solution is not possible in case of big values of *M* an *N*. This is the reason why a need to implement heuristic algorithms arises.

A. The heuristic of preference of machines

Let us mark by α^{e-1} the set of numbers of machines in which objects are serviced. This set is determined from the condition (16):

$$\exists_j \left(x_{i,j}^{e-1} = 0\right) \Rightarrow \left(i \in \alpha^{e-1}\right) \quad (16)$$

The machine A_i is free at the moment T_i^{e-1} which is determined from the equation (17):

$$T_i^{e-1} = \max_{1 \le j \le N} x_{i,j}^{e-1} \quad (17)$$

The earliest moment T_m^{e-1} of freeing machines is determined on the basis of the condition (18):

$$T_m^{e-1} = \min_i T_i^{e-1} \quad (18)$$

The machine A_m which becomes free the earliest is expected to serve the object ω_n which has not been served in this machine yet (19):

$$\beta_m^{e-1} = \left\{ j : \ x_{m,j}^{e-1} = 0 \right\} \quad (19)$$

The objects are available beginning with the moment Z_j^{e-1} where $Z_j^{e-1} = \max_{1 \le i \le M} x_{i,j}^{e-1}$.

The chosen object ω_n is available the earliest according to (20):

$$Z_n^{e-1} = \min_j Z_j^{e-1} \quad (20)$$

The function of generating states takes the form (21):

$$\exists_m \exists_n \left(x_{m,n}^{e-1} = 0\right) \Rightarrow \left[X^e = F\left(X^{e-1}, m, n_m\right)\right] \quad (21)$$

B. The heuristic of preference of objects

Let us mark by β^{e-1} the set of objects which are to be served in machines. This set must be determined from the condition (22):

$$\exists_{i}\left(x_{i,j}^{e-1}=0\right)\Rightarrow\left(j\in\beta^{e-1}\right) \quad (22)$$

The object ω_j is free at the moment Z_j^{e-1} which is determined on the basis of the formula (23):

$$Z_j^{e-1}=\max_{1\le i\le M} x_{i,j}^{e-1} \quad (23)$$

The earliest moment Z_n^{e-1} of freeing the object is determined as follows (24):

$$Z_n^{e-1}=\min_{j} Z_j^{e-1} \quad (24)$$

The object ω_n which is released the earliest must be allocated to the machine in which it has not been served (25):

$$\alpha_n^{e-1}=\left\{i:\ x_{i,n}^{e-1}=0\right\} \quad (25)$$

Machines A_i are available beginning with the moment T_i^{e-1} where $T_i^{e-1}=\max_{1\le j\le N} x_{i,j}^{e-1}$.
The machine A_m should be available the earliest: $T_m^{e-1}=\min_{i} T_i^{e-1}$.

The function of generating states takes the form (26):

$$\exists_{n}\exists_{m}\left(x_{m,n}^{e-1}=0\right)\Rightarrow\left[X^{e}=F\left(X^{e-1},n,m_n\right)\right] \quad (26)$$

C. The evolutional heuristic

According to the evolutional heuristic, in each state X^{e-1} the pair: machine A_m and object ω_n is chosen, which enables starting the service process in the system.

Let γ^{e-1} be the set of numbers of machines A_i and objects ω_j which meet the following condition (27):

$$\gamma^{e-1}=\left\{<i,j>:\ \ x_{i,j}^{e-1}=0\right\} \quad (27)$$

so the object ω_j can be allocated to the machine A_i.

The availability moment of the machine A_i in the state X^{e-1} is determined as follows (28):

$$T_i^{e-1}=\max_{1\le j\le N} x_{i,j}^{e-1} \quad (28)$$

Analogously, it is possible to determine the availability moment of the object ω_j:

$$Z_j^{e-1}=\max_{1\le i\le M} x_{i,j}^{e-1} \quad (29)$$

The moment of beginning servicing the object ω_j in the machine A_i is determined as follows (30):

$$r_{i,j}=\max\left(T_i^{e-1};Z_j^{e-1}\right) \quad (30)$$

The earliest moment of beginning servicing the object ω_n in the machine A_m is determined from the formula (31):

$$R_{m,n}=\max_{<i,j>} r_{i,j} \quad (31)$$

The function of generating states takes the form (32):

$$\exists_{m}\exists_{n}\left(x_{m,n}^{e-1}=0\right)\Rightarrow\left[X^{e}=F\left(X^{e-1},n,m_n\right)\right] \quad (32)$$

VII. 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 making 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. The three heuristic algorithms described in detail form an ideal basis for creating a simulator which is meant to prove the correctness of the approach presented hereby.

Acknowledgement

This paper was supported in part by project “Innovation of study programs at Silesian University in Opava, School of Business Administration in Karviná” Nr. CZ.1.07/2.2.00/28.0017.

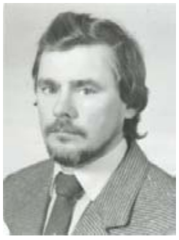
References

[1] U. Aickelin and A. Clark, Heuristic optimisation, in Journal of the Operational Research Society, 2011, Volume 62, Issue 2, pp. 251–252.
[2] R. Bucki and F. Marecki, Multi-stage Discrete Programming of the Production Line, Communications, Scientific Letters of the University of Zilina, Publishing Institution of Zilina University, Volume 1, 2013, pp. 62-67.
[3] R. Bucki and P. Suchánek, The Method of Logistic Optimization in E-commerce, in Journal of Universal Computer Science, Volume 18, Issue 10, 2012, pp. 1238-1258.
[4] Y. Chen, F.L. LIN and N. BI, The Modeling Analysis and Optimization of Production Logistics in the Discrete Manufacturing Enterprise Based on Multi-agent, Proceedings of the 13th International Conference on Industrial Engineering and Engineering Management, Volume 1. Issue 5, 2006, pp. 2185-2189.

[5] B. Chramcov and J. Balate, Model-building for Time Series of Heat Demand, in Annals of DAAAM for 2009 & Proceedings of the 20th International DAAAM symposium, Volume 20, 2009, pp. 195-196.
[6] V. Davidaviciene and L. Meidute, Quality of e-Logistics in e-Commerce: Consumer Perception, in Proceedings of Liberec Economic Forum, 2011, pp. 90-99.
[7] M. Dotoli, M.P. Fanti, A.M. Mangini and G. Tempone, Fuzzy Multi-objective Optimization for Network Design of Logistic and Production Systems, in ETFA 2005: 10th IEEE International Conference on Emerging Technologies and Factory Automation, Volume 1, pts 1 and 2, 2005, pp. 475-482.
[8] R. Farahani, S. Rezapour and L. Kardar, Logistics Operations and Management: Concepts and Models (Elsevier Insights), Elsevier, 1 edition, 2011.
[9] Y. Gardan and N. Gardan, Mathematical and Trade based optimization : "synthetic" method and three industrial cases, in Proceedings of the 2013 International Conference on Applied Mathematics and Computational Methods (AMCM 2013), 2013, pp. 201 – 207.
[10] P. Giribone, R. Revetria, F. Oliva, M. Schenone, EN. Nikolova, and GC. Peneva, Integrate clustering and mathematical programming for supporting reverse logistics optimization: Methodology and case study, Proceedings of the 6th WSEAS International Conference on System Science and Simulation, Book Series: Electrical and Computer Engineering, 2007, pp. 30 – 37.
[11] C. Gu, L. Estel, A. Yassine and S. Leveneur, Multi-Objective Optimization for Industrial Ecology: Design and Optimize Exchange Flows in an Industrial Park, in Proceedings of the 2013 International Conference on Applied Mathematics and Computational Methods (AMCM 2013), 2013, pp. 109 – 116.
[12] A. Karageorgos, N. Mehandjiev, G. Weichhart and A. Hammerle, Agent-based Optimization of Logistics and Production Planning, in Engineering Applications of Artificial Intelligence, Volume 16, Issue 4, 2003, pp. 335-348.
[13] D. Kofjac and M. Kljajic, Furniture Production Optimization with Visual Simulation and Genetic Algorithms, in Proceedings of 8th WSEAS International Conference on Simulation, Modelling and Optimization, Book Series: Mathematics and Computers in Science and Engineering, 2008, pp. 53 – 58.
[14] J. Loffelmann, Trendy a nové metody v oblasti plánování a řízení výroby, in IT Systems, annex No. 9, 2001, pp. 16 – 20.
[15] E.J. Macias and M.P. De La Parte, Simulation and Optimization of Logistic and Production Systems Using Discrete and Continuous Petri Nets, in Simulation-transactions of the Society for Modeling and Simulation International, Volume 80, Issue 3, 2004, pp. 143-152.
[16] V. Modrák, Using the Simulation Technique for Planning the Industrial Production in Metallurgy, in Metalurgia International, Volume 18, Issue 2, 2013, pp. 17-20.
[17] J. Nicholas, Lean Production for Competitive Advantage: A Comprehensive Guide to Lean Methodologies and Management Practices (Resource Management), in Productivity Press, 1 edition, 2010.
[18] C. Reis, L. Paiva and J. Moutinho, Genetic Algorithms and Sensitivity Analysis in Production Planning Optimization, in Proceedings of 10th WSEAS International Conference on Applied Informatics and Communications, Book Series: International Conference on Applied Informatics and Communications-International Conference on Biomedical Electronics and Biomedical Informatics, 2010, pp. 246-251.
[19] V. Řepa, Podnikové procesy. Procesní řízení a modelování, Praha: Grada Publishing, 2006.
[20] J.F. Shapiro, Modeling the Supply Chain. South-Western College Pub, 2006.
[21] HK. Song, KM. Kim, KT. Kim and HY. Youn, Application of Genetic Algorithm for Logistics Based on Multi-Agent System, in Proceedings of 2013 International Conference on Information Networking (Icoin), 2013, pp. 309-314.
[22] P. Suchánek, Business Intelligence - The Standard Tool of a Modern Company, Proceedings of the 6th International Scientific Symposium on Business Administration: Global Economic Crisis and Changes: Restructuring Business System: Strategic Perspectives for Local, National and Global Actors, 2011, pp. 123-132.
[23] P. Suchánek, E-commerce – Elektronické podnikání a koncepce elektronického obchodování. Praha: Ekopress, 2012.
[24] Synext, Štíhlá výroba – Lean Production. 2008. [Cited 2013-02-10]. Available from: http://www.synext.cz/stihla-vyroba-lean-production.html.
[25] R. Šperka, M. Spišák and K. Slaninová, Control Loop Model of Virtual Company in BPM Simulation, in Soft Computing Models in Industrial and Environmental Applications, Volume 188, 2013, pp. 515-524.
[26] D. Vymětal, Value Chain and Process Models: Is the Gap between them Real?, in Proceedings of Distance Learning, Simulation and Communication 2009, pp. 198-205.
[27] X.S. Wang, J.L. Zhang, and H.X. Zhao, The Optimization of Small and Medium Manufacturing Enterprises' Production Logistics System Based on TOC, in Applied Economics, Business and Development, Volume 208, 2011, pp. 395-401.
[28] L. W ilson, How to Implement Lean Manufacturing, McGraw-Hill Professional, 1 edition, 2009.
[29] M. Wooldridge, An Introduction to Multi Agent Systems, Wiley, 2009. 484 p.

Petr Suchánek, Doc., Mgr., Ph.D. was born in 1974 in Karviná. He graduated from University of Ostrava at the Faculty of Science in 1997. He received his Ph.D. in Automation of Technological Processes at the Faculty of Mechanical Engineering at Technical University of Ostrava in 2003. He has been habilitated in the field Systems Engineering and Informatics in 2013. He is an experienced researcher dealing with e-business and e-commerce systems for the last 15 years. He has written a number of papers about e-commerce system architecture, e-commerce system modeling, security of e-commerce systems, e-shop website security etc. Some of the papers are in Web of Science and/or SCOPUS. He lectures on e-business, portal management, geographical information systems and programming at the Silesian University in Opava, School of Business Administration in Karviná.

Rober Bucki, Ing., Ph.D. graduated from Agricultural University in Prague in 1986 where he studied at the Mechanization Faculty. He received his Ph.D. in Computer Science at The State Scientific and Research Institute of Information Infrastructure in Lviv in 2004. He is the assistant professor at The Institute of Management and Information Technology in Bielsko-Biała. His scientific interests include mathematical modeling of logistic processes, computer simulation and modeling in computational linguistics. He is the author and co-author of more than 50 scientific articles and conference papers as well as 6 monographs. He has been involved actively in international projects which focus on logistic processes.



Franciszek Marecki, Prof., Ph.D. received a Ph.D. in technical sciences in the field of automatisation from Silesian University of Technology in 1976. He habilitated in technical sciences at Silesian University of Technology in 1986. He also received Ph.D. in economic sciences at University of Economics in Prague in 1988. Moreover, he was rewarded the scientific title on par with a professor by The State Scientific and Research Institute of Information Infrastructure, The Ukrainian Academy of Sciences in Lviv. At the present moment he is lecturing at Institute of Management and Information Technology in Bielsko-Biała and Academy of Business in Dąbrowa Górnicza. He specializes in information technology and management. He is the author and co-author of more than 100 scientific articles and conference papers as well as numerous monographs.

Eva Litavcová, Mgr., Ph.D. graduated from University of Pavol Jozef Šafárik in Košice at the Faculty of Science in 1987. She participated in a lot of researches during previous work as an analyst in the field of statistics up to 2009. She received her Ph.D. in Management at the Faculty of Management at Prešov University in Prešov in 2010. She works there as an assistant professor at the Department of Quantitative Methods and Managerial Informatics. Scientific interests: applied statistics, mathematical modelling.