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IT SYSTEMS SUPPORTING THE MANAGEMENT OF PRODUCTION CAPACITY

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Abstract:
The paper presents the problem of manufacturing process flexibility in view of a company's material and information flow stream management. The author of the article has described the functions of a production process control system and presented the characteristics of production capacity intensive and extensive reserves. The MRP II/ERP, MES and APS class IT tools supporting the process of production planning, organization and control have also been discussed.

Key words: *production control system, MRP, MES, APS, intensive and extensive reserves*

INTRODUCTION

Currently, changes in production systems are determined by customers' requirements [9, 27], technological advances [16, 28] and the implementation of IT solutions in processes [22]. The basic direction of production systems development is to increase the flexibility of a production process and to improve the quality of products. Decisions in this regard are taken at various levels of the organization [5, 10, 14, 17, 19, 26]. The achievement of satisfactory results in production activity is determined by the coordination of tasks carried out on three levels: changes in the operations of a technological process as a component of the primary production process, modification of the whole production process and company's organizational transformations.

Changes in the area of technological operations are among others related to the construction of technological equipment and the type of tool materials used. These changes are evolving towards complete and precise machining. Activities within the scope of the whole production process modification include integrating the basic production processes with auxiliary ones and are related to the process of product distribution, customer sale and maintenance service as well as the process of market research and production preparation [1].

On the other hand, organizational transformations of a company include activities focused on optimizing the business processes and company's organizational structures [4]. For the effectiveness of adjusting a production company to the changing conditions of the environment depends on the efficient control of the quantity and type of the company's material and information flow.

FUNCTIONS OF A PRODUCTION CONTROL SYSTEM

The production flow control process is carried out by using the following functions: planning, manufacturing, recording and coordination of activities [6]. The coordination of activities, however, should be considered in three stages [7]: tactic, strategic and analytical (Fig. 1). Tactic planning is related to both the process of production technical preparation and the establishing of the company's production capacities. This stage results in a definition of the product technology and structure as well as a description of the availability of defined machine and human resources in relation to the qualifications or possibilities of completing particular production tasks.

Strategic planning determines the direction of economic activity development based on the sale quantity and value data from previous periods or on the size of the orders placed and the planned production. On the other hand, the coordination of activities at the analytical stage involves determining the cause-and-effect relationships of the production process completion. The correct interpretation of signals from the environment and proper concluding are of vital importance in the process of adjustment and elimination of departures. The reason for departures among others include: breakdowns, defects, untimely deliveries of materials as well as untimely collection of products, order priority and others.

Production flow monitoring makes it possible to compare the size of the projected production with the actually obtained one, providing a basis for decisions related to: technological and workstation directives, quantitative correction of the current plans as well as the construction of a production planning operational algorithm.

COORDINATION OF ACTIVITIES

The literature quotes a number of definitions of the notion of production capacity. Its synonyms include: manufacturing system productivity, production output or capability [3, 11, 20, 21]. In general understanding, production capacity is a capability to manufacture products or provide services the value of which is accepted by a customer, at a specific time and in the amount resulting from the availability and production possibilities of the system resources.

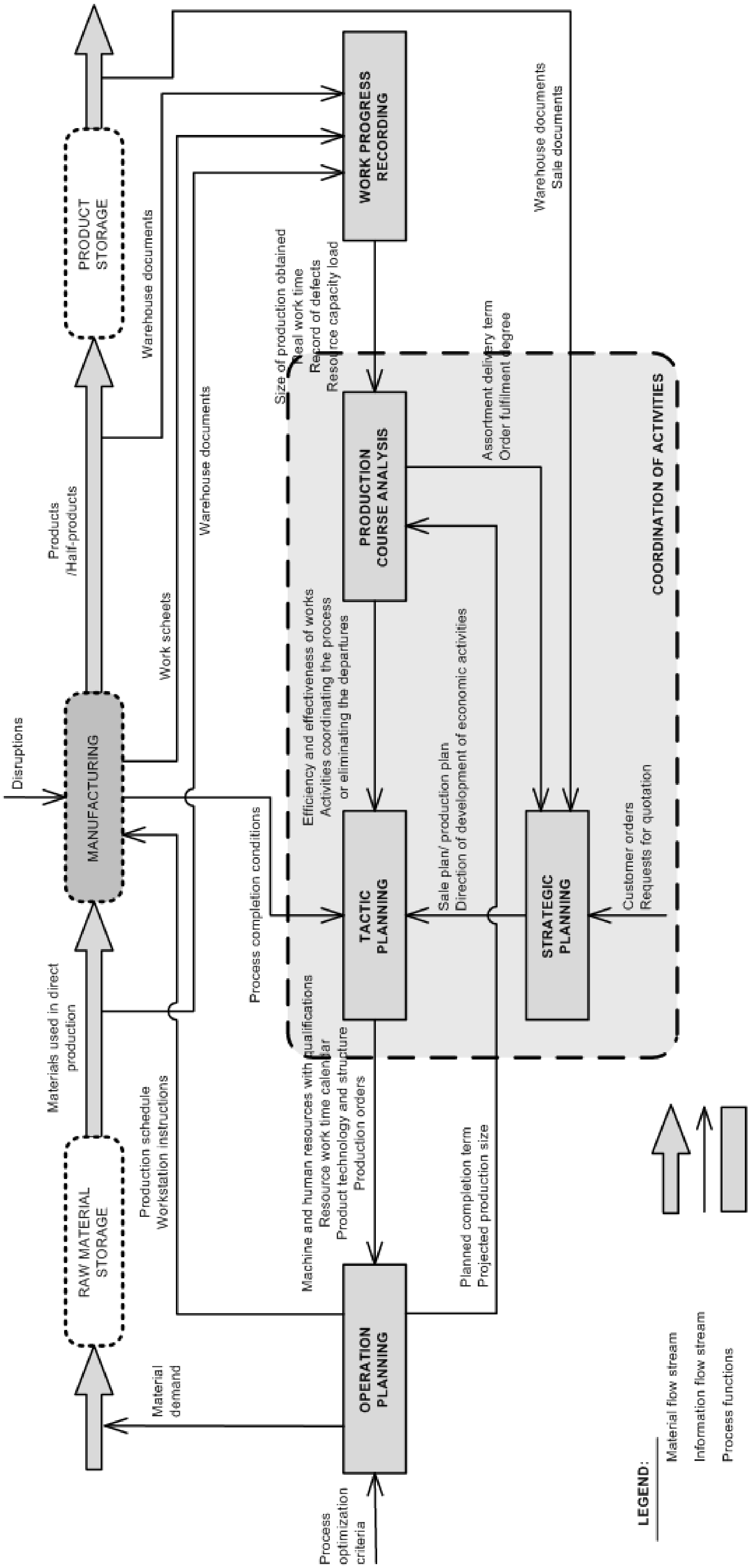

Fig. 1 A general diagram of a production flow control system

Production capacity is established on the basis of optimal technical and economic standards which define the real and maximum use of equipment and the production area, while taking into consideration the best conditions of the production and work organization process. The calculations of a production capacity are based on components of a basic manufacturing process. The factors which determine the size of production capacity include:

- production factors consisting of:
  - machine resources with technical characteristics,
  - human resources with qualifications and skills,
  - the size of a production area,
- the structure of assortment, which is determined by:
  - physical and mechanical properties of direct production materials,
  - the offered assortment range,
- the organisation of production defined by:
  - the technology and structure of a product,
  - the time of machines and technical equipment use,
  - the type of production,
- demand expressed in the quantity, assortment and quality of products needed,
- disruptions resulting among others from [13, 15]:
  - the scope of external cooperation,
  - the scope of failure and machines repair time,
  - changes in employment,
  - substitute modification of products,
  - price diversification,
  - changes in the intensity of marketing activities,
  - the use of bookings and order priorities.

All the above mentioned factors are changeable. Due to the risk and uncertainty of economic processes, it is necessary to have production capacity reserves [6, 8, 12]. They are a difference between the size of a calculated production capacity and the obtained size of the enterprise production. The size of reserves should be optimised, taking into account the maintenance costs and a change in market demand. The knowledge of reserves in particular production cells is important from the point of view of the proper division of production tasks between organisational units as well as the specialization of work cells and workstations and the establishing of a proper direction of the company's modernization and investment. Reserves fall into two basic categories [21]:

- intensive,
- extensive.

Intensive reserves are connected with the shortening of working time needed to manufacture a unit of the product and result from:

- the intensification of technological processes,
- a reduction in auxiliary time owing to the automation of activities,
- elimination of non-production use of machines related to:
  - production defects repair,
  - additional works due to departures from the planned technology,
  - non-rational division of tasks among exchangeable workstations,
  - or improper use of machines.

On the other hand, extensive reserves are related to the possibility of increasing the time of machines and technical equipment use and increasing the production area capacity. Extensive reserves include the majority of downtimes resulting from:

- organisational and technical shortcomings,
- the lack of workstation staff,
- and breakdowns or repairs of machines.

Machine downtimes caused by the lack of materials, tools, electricity and production orders are dependent on the adopted manner of planning and supplying the workstations. In many enterprises, short-lasting breaks which occur during a working day due to the fault of an employee are a considerable reserve of production capacity. They include: coming late to work, finishing work too early, absence at a workstation etc.

A full evaluation of possibilities to increase the level of production capacity use requires an analysis of intensive and extensive reserves. Investigations into intensive reserve components allow determining the labour consumption of the unit of a product, taking into consideration the time of basic, auxiliary and supplementary production process. On the other hand, the analysis of extensive reserves involves assessing the production availability of manufacturing machines and equipment. The size of extensive and intensive reserves indicates the rank of particular functions of a production flow control system (Fig. 1), as the increasing of production capacity by using the intensive reserves is performed by an operational planning function, while the management of extensive reserve size is carried out by the function of work progress recording [3].

IT SYSTEMS SUPPORTING THE CONTROL OF PRODUCTION

Currently, the foundation of the production process management and material flow control in the company as well as a basic condition for the integration of economic activities is the implementation of IT systems, which support the obtaining, processing and transferring of information.

The obtaining of information

Information which describes the level of a manufacturing process completion may be obtained:

- with the participation of workers employed in direct production,
- as well as by means of the transfer of data obtained directly from production machines and equipment.

Sources of information are (Fig. 1):

- the recording of working time,
- the recording of warehouse documents,
- and the classification of production defects.

In the vast majority of cases, the standard functionality of MRP II (Manufacturing Resource Planning)/ERP (Enterprise Resource Planning) enables the recording of events only with the participation of a human factor. A solution which makes it possible to obtain information directly from a production line by means of automatic identification and industrial automation equipment (sensors, industrial controllers, testing systems) is the implementation of MES class systems (MES – Manufacturing Execution System). It should be noted that the recording of working time as well as the recording of warehouse documents can be carried out by means of both kinds of systems.

An important element which differentiates the applied solution is the accuracy and relevance of data being a basis for further analysis. It is obvious that unreliability and labour consumption related to manual recording of events by an employee is the main factor reducing the efficiency of a process organization. The incorrect input of data or excessive workload imposed on employees within a short period of time result in considerable delays in the recording of data, distort the picture of work progress and make the analysis of the current situation impossible [18, 19]. The basic benefits of data recording process automation include [18]:

– integrity of the material and information flow,
– and data update.

A direct consequence of the systematic recording of work progress is:

– following the current level of production plans completion,
– follow-up control of the product quality and process parameters,
– and shortening of the process completion time.

On the other hand, the proper interpretation of data and effective concluding may among others contribute to [16]:

– the identification of the causes of downtimes and breakdowns,
– the identification of product genealogy,
– the reporting of process indicators, among others: working time, efficiency of resources and product quality,
– the identification of the degree of order fulfilment,
– the reduction of material defects, machine unreliability or unavailability of employees,
– the influence on the quality parameters of a manufactured product,
– a more effective control over the condition and size of warehouse stocks,
– a better use of the production potential,
– the analysis of real production costs and evaluation of the profitability of undertaken tasks,
– and the improvement of customer service quality.

The analysis of MRP II/ERP and MES systems functionality reveals that the areas of application of both systems overlap. Some modules of MRP II/ERP class systems may contain a part of MES system functionality, whereas an MES class system can carry out certain basic tasks of MRP II/ERP. Figure 2 presents the location of an MES system in the general structure of information flow, taking into consideration the production processes of an enterprise. An important issue in the cooperation of both systems is the integration of system data and the two-way direction of data transfer. Integration applies to basic data, which maps the structures and processes of a company, as well as transactional data created in the process of economic events recording [2, 24].

Data processing

The obtaining of an efficient material and information flow control system in a company is not only connected with the time of data recording or precise determination of control and measurement points of the material flow stream, but is also determined by the operational planning of production activities (Fig. 2). The adequacy of a schedule depends on [18]:

– the completeness of basic data describing the control system elements,
– the degree of material flow stream description parametrization,
– the adopted criteria of production processes optimization,
– and the dynamics of changes in the control system and environment.

The majority of MRP II/ERP class systems enable a comprehensive description of control system elements, but unfortunately the implemented planning algorithms do not offer a sufficient parametrization of material flow streams and their criteria of process optimization are considerably limited.

An alternative solution in production activities scheduling and logistic processes planning is provided by APS (Advanced Planning Scheduling) systems. Their advanced algorithms enable automatic creation of production course scenarios, taking into consideration the specific character of processes in an enterprise [23]. APS class systems may therefore perfectly complement MRP II/ERP systems [25] (Fig. 2).

The performance of operational planning functions supported by tactic planning activities is in this context the range of data processing and comprises the full area of production capacity intensive reserve management. Another, equally important, aim of data sets processing is the coordination of analytical activities (Fig. 2) carried out on three levels [5]: changes in the area of technological operations, modification of the whole production process and organizational transformations of a company. In the vast majority of enterprises, the concluding and undertaking of adaptation activities on each of the above mentioned levels is carried out solely with the participation of a human factor. The IT systems support in the area of changes is limited to the preparation and updating of system data sheets.

Giving instructions

A differentiated approach in the manner of intensive and extensive reserve evaluation, and in consequence, the diversity of the implemented IT tools supporting the management of production capacity and production flow control is a key issue in activities which increase the flexibility of the manufacturing process and improve the quality of a product [6]. The main factors influencing the adopted solutions quality include:

– the degree of material flow description parametrization,
– the planning process optimization criteria,
– the range of system data integration and the direction of data transfer,
– the dynamics of changes in the control system and environment,
– and the direction of the modernization process and company's investment.

The manner of production activity mapping in IT systems, the scope of system data integration and the dynamics of changes in a manufacturing process determine the length of an information flow control cycle, within the framework of which the task of obtaining, processing and transfer of data is performed. The higher the number of information flow control cycles in a production cycle, the greater flexibility of the manufacturing process. The automation of information flow in a production control system allows the production capacity to be increased and the size of intensive and extensive reserves in an enterprise to be optimized. The automated flow of information, however, requires narrowing the scope of processed data to production system changes which have a non-investment character (Fig. 3).

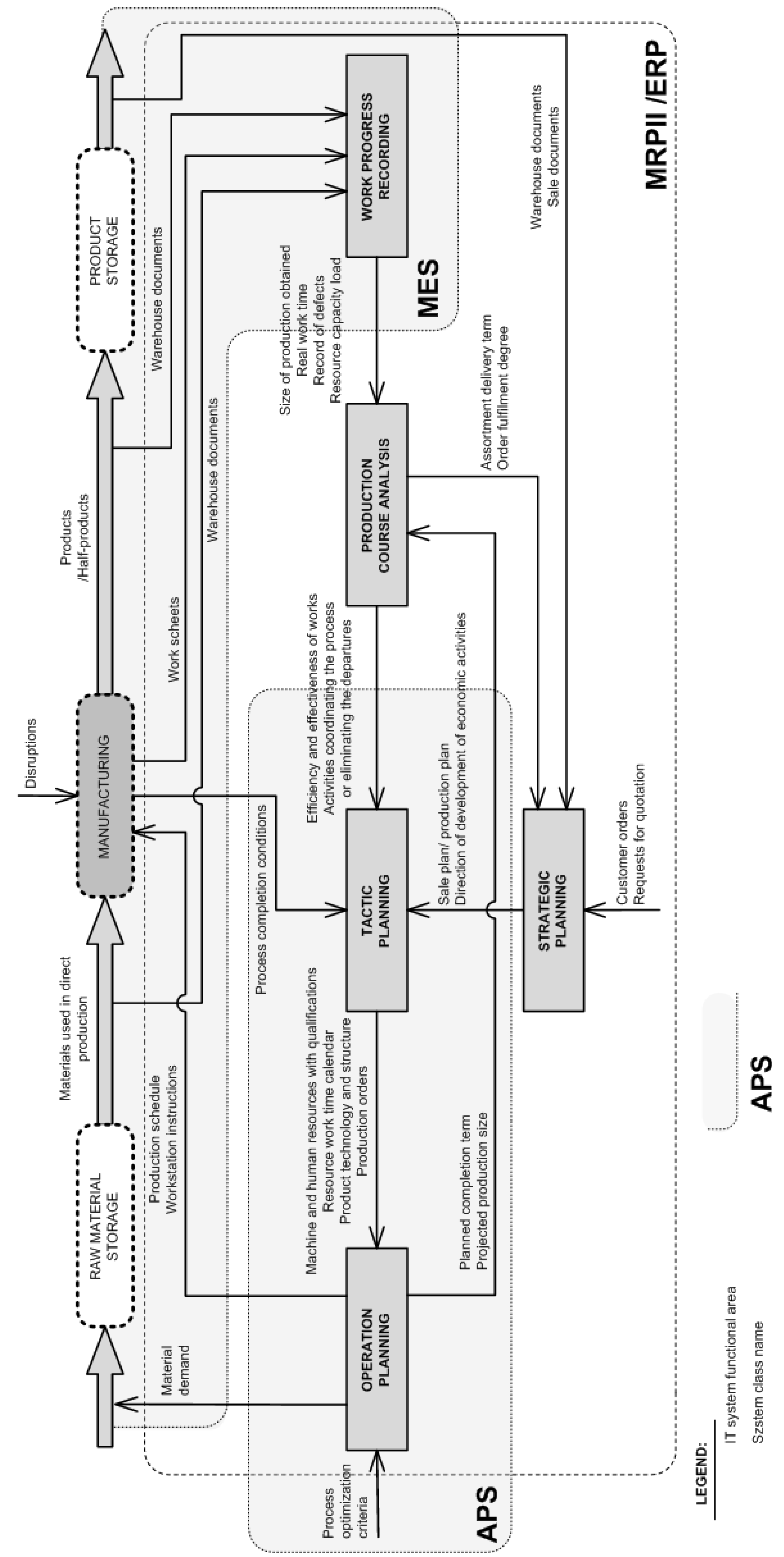

Fig. 2 The functional area of IT systems which support the production control

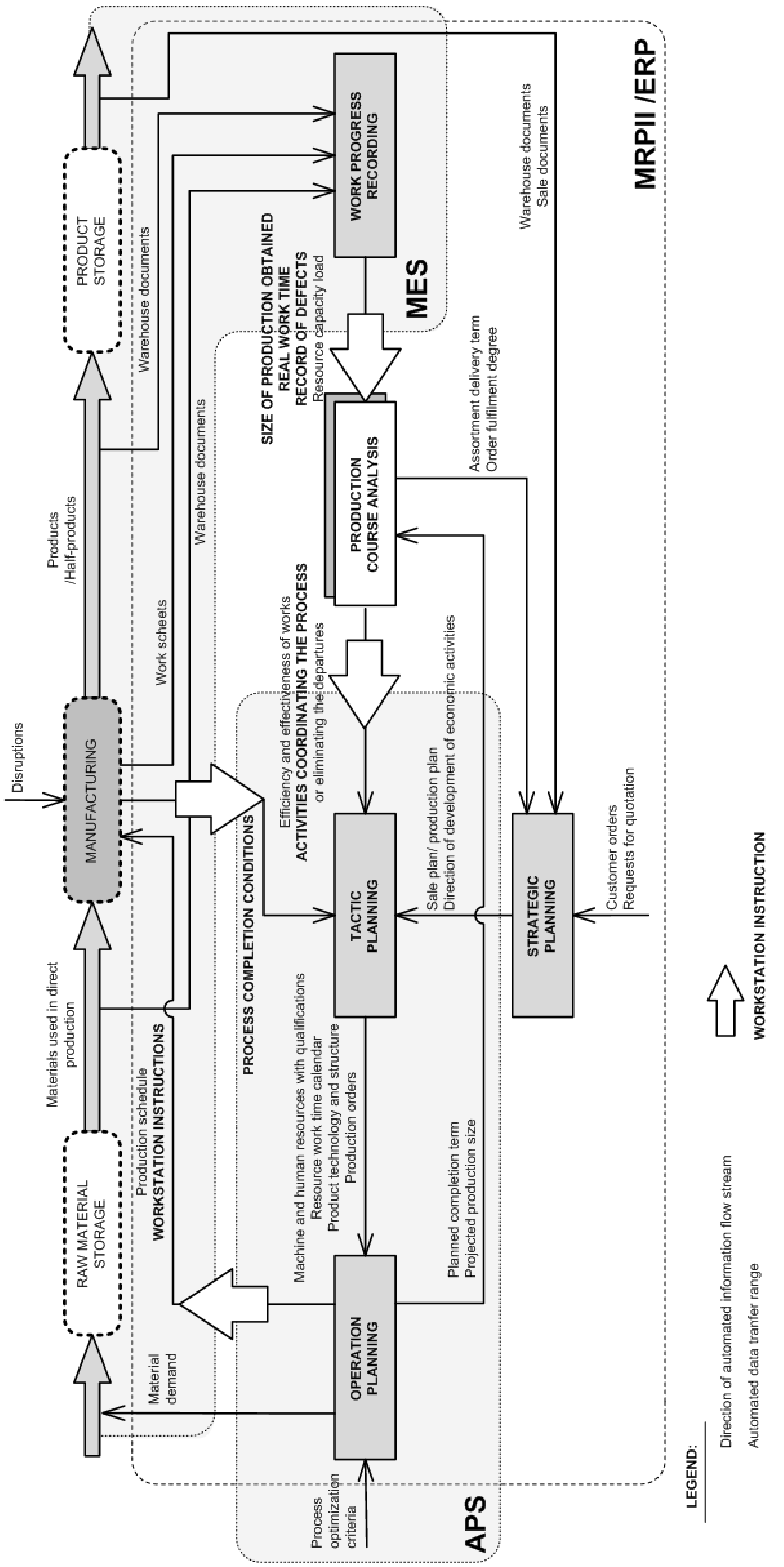

Fig. 3 The automation of information flow stream in a production control system

Due to the strategy of an enterprise economic activity development, the increasing of production capacities, which results from the use of additional financial sources, should be carried out solely by the operator's decisions. Investment activities among others include:

- increasing the number of shifts,
- technological process modernization,
- increasing the production potential,
- or cooperation systems exchange.

The direction of a stream and the scope of available data transfer in an automated flow of information have been presented in Fig. 3. There are four transfer nodes which are particularly important for the cyclic nature of an information flow control process.

CONCLUSIONS

Changes in the modern environment force enterprises to modify their behaviours. A solution which enhances the flexibility of activities and the effectiveness of production seems to be the implementation of IT systems which support processes. The production planning and control is supported by the functionality of MRP II/ERP, MES and APS class systems. However, irrespective of the class of a system that a company decides to implement, the introduction of IT solutions in the enterprise processes allows rivalling the competitors and is one of the ways an enterprise can develop in the era of world economy globalization. The automation of information flow in a production control system makes it possible to increase the level of production capacity use and optimize the size of the company's intensive and extensive reserves.

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REFERENCES

[1] ANSI/ISA-95.00.03-2005. *Enterprise-control system integration. Part 3: Activity models of manufacturing operations management*, 2005. ISBN 1-55617-955-3.
[2] A. Atamturk, M.W.P. Savelsbergh. „Integer programming software systems". *Annals of Operations Research*, vol. 140(1), 2005, pp. 67-124.
[3] R. Basu, J.N. Wright. „Resource and capacity management". *Total Supply Chain Management*. Chapter 5, 2008.
[4] M. Berglund, J. Karlun. „Human, technological and organizational aspects influencing the production scheduling process". *International Journal of Production Economics*, vol. 110(1-2), 2007, pp. 160-174.
[5] P.M.M. Bongers, B. H. Bakker. „Application of multistage scheduling". In proceedings of 16th ESCAPE. *Computer Aided Chemical Engineering*, vol. 21, 2006, pp. 1917-1922.
[6] M. Brzeziński (Ed.). *Organizacja i sterowanie produkcją. Projektowanie systemów produkcyjnych i procesów sterowania produkcją*. Warszawa: A.W. Placet, 2002.
[7] O. Rogelio, W. Noel. „Cross-functional alignment in supply chain planning: A case study of sales and operations planning". *Journal of Operations Management*, vol. 29(5), 2011, pp. 434-448.
[8] P.M. Castro, L.J. Zeballos, C.A. Méndez. „Hybrid time slots sequencing model for a class of scheduling problems". *AIChE Journal*, vol. 58(3), 2012, pp. 789–800.
[9] M. Christopher. *Logistics and Supply Chain Management: Creating Value-Adding Networks*. London: Pearson Education Limited, 2005.
[10] S. Chopra, P. Meindl. *Supply chain management: strategy, planning and operation*. New Jersey: Upper Saddle River, 2003.
[11] I. Durlik. *Inżynieria zarządzania. Strategia i projektowanie systemów produkcyjnych*. Warszawa: A.W. Placet, 1995.
[12] M.C. Georgiadis, A.A. Levis, P. Tsiakis, L. Sanidiotis, C.C. Pantelides, L.G. Papageorgiou. „Optimisation-based scheduling: A discrete manufacturing case study". *Computers & Industrial Engineering*, vol. 49(1), 2005, pp. 118-145.
[13] Z. Li, M. Ierapetritou. „Process scheduling under uncertainty: Review and challenges". *Computers & Chemical Engineering*, vol. 32(4-5), 2008, pp. 715-727.
[14] A.G. De Kok, S.C. Graves (Eds). „Handbook in operations research and management science". *Supply Chain Management: Design, Coordination and Operation*, vol. 11, 2003, Amsterdam: Elsevier, pp. 457-524.
[15] S. Kreipl, J.D. Dickersbach. „Scheduling coordination problems in supply chain planning". *Annals of Operations Research*, vol. 161(1), 2008, pp. 103-122.
[16] C.T. Maravelias, C. Sung. „Integration of production planning and scheduling: Overview, challenges and opportunities". *Computers & Chemical Engineering*, 33 (12), 2009, pp. 1919-1930.
[17] H. Meyr, M. Wagner, J. Rohde. „Structure of Advanced Planning Systems". In: H. Stadtler, C. Kilger (Eds). *Supply Chain Management and Advanced Planning. Concepts, Models, Software and Case Studies*. Berlin: Springer, 2005, pp. 109-115.
[18] E. Milewska. „Wykorzystanie narzędzi informatycznych w procesie sterowania strumieniem przepływu materiałowego". *Mechanik*, vol. 84(7), 2011, pp. 575-582.
[19] E. Milewska. „Sterowanie strumieniem przepływu zasobów na przykładzie produkcji naczyń kamionkowych", *Ekonomika i Organizacja Przedsiębiorstwa*, vol. 5, 2009, [in: CD], In proceedings of 6th International Scientific Conference „Systems Supporting Environment Management", pp. 83-92.
[20] E. Pająk. *Zarządzanie produkcją. Produkt, technologia, organizacja*. Warszawa: PWN, 2006.
[21] K. Pasternak. *Zarys zarządzania produkcją*. Warszawa: PWE, 2005.
[22] J. Rohde, M. Wagner. „Master Planning". In: H. Stadtler, C. Kilger (Eds). *Supply Chain Management and Advanced Planning. Concepts, Models, Software and Case Studies*. Berlin: Springer, 2005, pp. 159-177.
[23] H. Stadtler. „Supply chain management and advanced planning – basics, overview and challenges". *European Journal of Operations Research*, vol. 163, 2005, pp. 575-588.
[24] M. Taal, C.J. Wortmann. „Integrating MRP and finite capacity planning". *Production Planning and Control*, vol. 8(3), 1997, pp. 245-254.

[25] V.C.S Wiers. „A case study on the integration of APS and ERP in a steel processing plant”. *Production Planning and Control*, vol. 13(6), 2002, pp. 552-560.
[26] V.C.S. Wiers, W.T. Van Der Schaaf. „A framework for decision support in production scheduling tasks”. *Production Planning and Control*, vol. 8(6), 1997, pp. 533-544.
[27] J.C. Wortmann, D.R. Muntslag, P.J.M. Timmermans. *Customer-driven manufacturing*, London: Chapman & Hall, 1997.
[28] J. Wu, M. Ulieru, M. Cobzaru, D. Norrie. *Supply Chain Management Systems: state of the art and vision*, In proceedings of 9th International Conference on International Conference on Management of Innovation and Technology IEEE, 2000, pp. 759-764.

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