doi:10.22306/al.v7i4.174 *Received: 17 May 2020; Revised: 05 Sep. 2020; Accepted: 01 Oct. 2020*

TRANSFORMATION THE LOGISTICS TO DIGITAL LOGISTICS: THEORETICAL APPROACH

Miriam Pekarčíková
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovak Republic, EU,
miriam.pekarcikova@tuke.sk (corresponding author)

Peter Trebuňa
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovak Republic, EU,
peter.trebuna@tuke.sk

Marek Kliment
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovak Republic, EU,
marek.kliment@tuke.sk

Milan Edl
University of West Bohemia, Faculty of Mechanical Engineering, Department of Industrial Engineering and Management, Univerzitni 8, 301 00 Plzen, Czech Republic, EU,
edl@fst.zcu.cz

Ladislav Rosocha
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovak Republic, EU,
ladislav.rosocha@tuke.sk

Keywords: digitalization, decoupling point, supply chain, Kanban, MRP

Abstract: In connection with Industry 4.0, professional publications are mostly focused on the introduction of new technologies, research of new and intelligent materials, etc. which mean evolution compared to the present. However, it is also necessary to focus on the implementation of the product within the supplier-customer relationship, as the customer's impact on the final product is significant. The article deals with the transformation of the Supply Chain using the DDMRP methodology, which aims to maintain best practices, address their shortcomings, and integrate pull-based replenishment tactics. It is a comprehensive tool that integrates the entire Supply Chain, including the integration of customers and suppliers.

1 Introduction

Since manufacturing companies, trading companies, transport companies, etc. are dependent on the timely provision of input materials, implementation of handling and transport activities in the production and distribution of products, provision of activities in warehouses, logistics is the key factor, which has the appropriate methods, techniques, and tools to effectively manage these activities. The integrated logistics system in the company should be based on the business strategy and ensure a shortening of innovation cycles, global supplier-business-customer interconnection, customization of products, and logistics services using integrated information and communication technologies. Logistics can, therefore, be understood as customer-oriented planning and management of business value chains through information technology support. Decentralization of management and autonomy of individual company structures that are synergically synchronized became the basis for the application of cyber-physical systems/CPS into production, creation of information and communication networks between objects and systems, implementation of systems for collection, analysis, and evaluation of large data volumes and virtual creation space for the contact between internal and external environment [1-4].

These are new approaches in the organization and management of production. Instead of conventional pressure control systems of production control, each product (intelligent element) will control itself, i.e. selects the processing sequence and determines the machine, resp. equipment for the operation in time will provide the means for its processing and handling (tools, transport elements, etc.). Production facilities and logistics elements will also be regulated separately and linked to the product through highly efficient information and communication systems. Interconnection of technologies with production processes through communication technologies and the introduction of so-called methods Self –X properties (self-regulation, self-configuration, self-diagnostics, self-optimization, self-protection) allow for autonomous resp. partially autonomous activities of machines and equipment, resp. logistics elements, which increases flexibility and efficiency. It opens up the ability to process large amounts of data in real-time, without interfering with real systems and processes to create a virtual environment, using digital technology and implementing digital models to create a digital environment, creating a new environment for the development of Industry 4.0. Communication and collaboration of people, intelligent machines, devices, logistics, and products is the main purpose of Industry 4.0 [5-8].

1.1 Characteristics of Logistics 4.0

In Industry 4.0, products, manufacturing systems, warehouses are connected to global production networks. In this way, it is possible to communicate with each other, to move available data, to trigger processes, while still leaving these entities room for autonomous self-control and optimization. Smart products can be identified at different stages, knowing their history, real state, and suggesting alternative ways to complete. Intelligent manufacturing systems are involved in other companies' business processes, IT systems, and play an important role in the value chain within the production network [9-11].

Today's businesses store a wealth of information and data about their products, variants, manufacturing processes, workers, suppliers, customers within their enterprise software, but they are not able to complete and efficiently process data from different areas. When moving to the so-called smart production supported by smart logistics is first of all necessary to electronically record, organize, complete and create a software information network with the help of software support, which will create the possibility of management and coordination of all production and non-production operations - production, logistics, quality control, maintenance, etc. [12-14].

This information and communication system will enable us to receive and process information in real-time and to solve the necessary measures. The production manager will know exactly where the part is in the production, what operation is being carried out on it, at what stage of the production cycle it is, who is the operator at the machine, what fault occurred, what machine, when it was rectified, how long who repaired it, etc. All of this is very important information that streamlines the production process in real-time. Regarding non-production processes, information is available regarding actual costs, suppliers, customers, inventory movements and inventory levels in the entry depots, distribution depots, spare parts depots, and commissioning information. This is conditioned by the implementation of key elements:

1. implementation of sensors for continuous automatic data collection from production equipment, production lines, transport equipment, storage facilities and warehouses, materials, parts,
2. creation of an information and communication network between all objects and subjects of the enterprise's value flow,
3. application of intelligent data creation software, i.e. collecting, processing, analysing, and evaluating the collected data.

1.2 Trends in Digital Supply Chain

The goal of the Digital Supply Chain is integrated planning and management of logistics systems and networks based on digital models, methods, and tools that are built on a common flexible information and communication platform. Currently known and used tools focus on creating a digital business, where digital models can be heterogeneous, resp. usable in several projects.

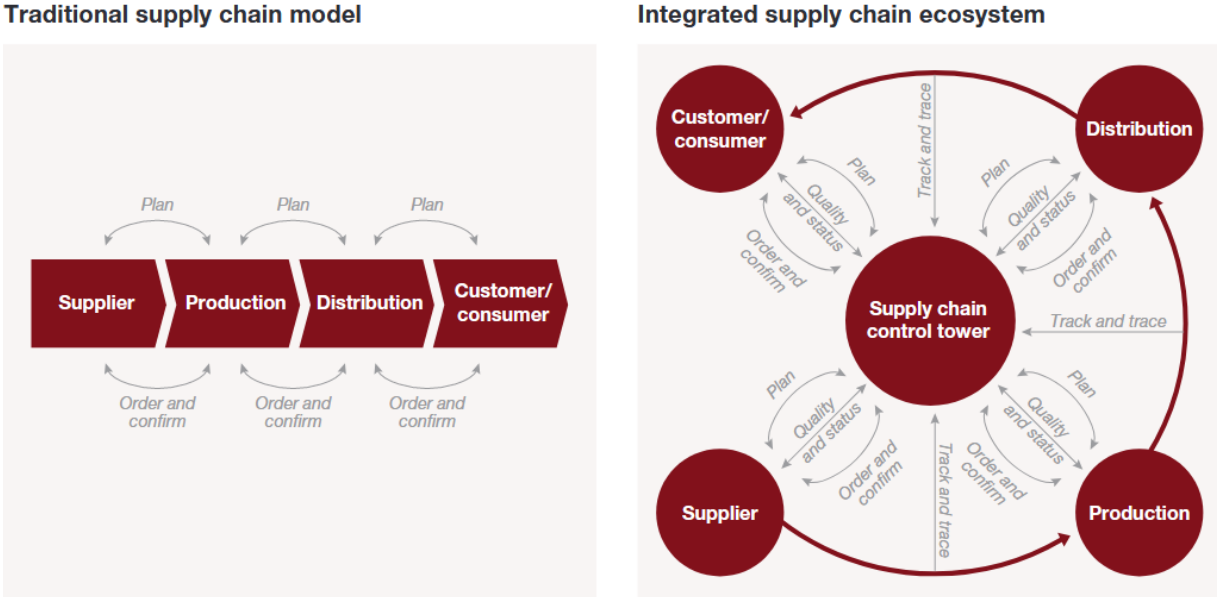

Figure 1 Complexity of Digital Supply Chain [15]

The indicator of the transformation of the supply chain into the smart supply chain is, on the one hand, the pressure from the introduction of new technologies into business processes and systems due to Industry 4.0, and on the other hand, a new concept of input procurement is being developed in combination with capacity management to ensure flexible supply dimensioning. Integrated procurement logistics aims to produce forecasts of product needs in a timely, long-term, and medium-term planning horizon. Methods and techniques for forecasting future consumption are being developed and attempted to reflect as closely and accurately as possible the course of consumption in the past. The complexity of the Supply Chain is shown in Figure 1.

Unlike traditional supply systems, the new dynamic approach to inventory management is that it considers unique procurement methods, unique demand and product flows through the production process. The aim is to define what level of inventory can provide the required level of supply service, ensure the efficiency of material flows in production, and compensate for fluctuations in demand. A key role in balancing supply and demand is the optimization of the company's inventory. The solution to the causes of overcrowded warehouses is also possible through modern information and communication technologies. It is important to gain control over what is in the warehouse and what scope of activities the warehouse provides. The aim is to provide system support for logistics processes using the principles of Lean Manufacturing, i.e. electronic records of movements of individual items in stock, material flow management upon receipt, quality control, stocking, out of stock to production, and preparation for dispatch. [15-18]. The effects of technology pressure and demand-pull in the digital supply chain are shown in Figure 2.

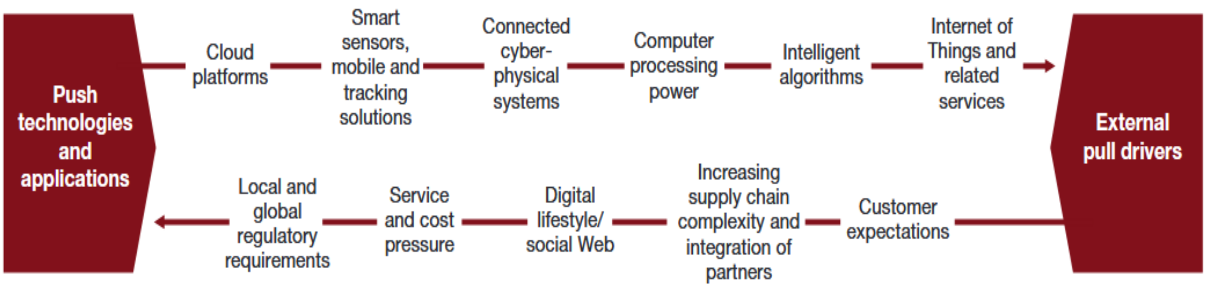

Figure 2 Effects of technology pressure and demand-pull in the digital supply chain [15]

The main benefit of introducing new information and communication technologies in combination with robotization, standardization of logistics processes is to accelerate the material flow, reduce errors in material handling and efficient use of storage areas, refine information flow, and work with information in real-time. Successful implementation of the Internet of Things in logistics technology requires intensive cooperation and a high level of participation by individual entities in creating value along the entire Supply Chain, to create a prosperous information and communication space, i.e. create an interconnected intelligent logistics network of the production process that will create added value through communication between relatively autonomous entities, thereby achieving speed, flexibility, and quality of value flow. The convergence of the physical world with the digital world is now a new paradigm of the autonomous and decentralized world of production.

2 Methodology for increasing flexibility of Supply Chain

2.1 Demand-driven Supply Chain

The disadvantage of the often-used MRP software system in practice is the lack of visibility of orders well in advance so that production and purchasing can be planned correctly. Demand in the MRP system is largely derived from the forecast. Subsequent adjustments are made near the point of the visibility of the order. End item order scheduling begins at the beginning of the planning horizon, extending the response time. The longer the so-called cumulative delivery time (procurement and production cycle), the longer the planning horizon. The longer the planning horizon, the less accurate the planning of orders, which necessitates subsequent corrections. Another element to consider is the time of customer tolerance. Ideally, it would have to be at least the same resp. higher than the cumulative delivery time. Figure 3 shows the planning time horizon vs. order visibility horizon.

MRP is a system that allows companies to quickly recalculate and synchronize total material requirements and dependencies according to a defined input demand. This is especially important for complex BOMs or many shared components. As there are currently many more connections and dependencies between the individual components, the importance of MRP, despite its imperfections, is undoubtedly growing. MRP plays an important role in the modern supply chain, but there is a need to increase its agility. The first building block on the way to achieving a more agile MRP system is to create suitable decoupling points.

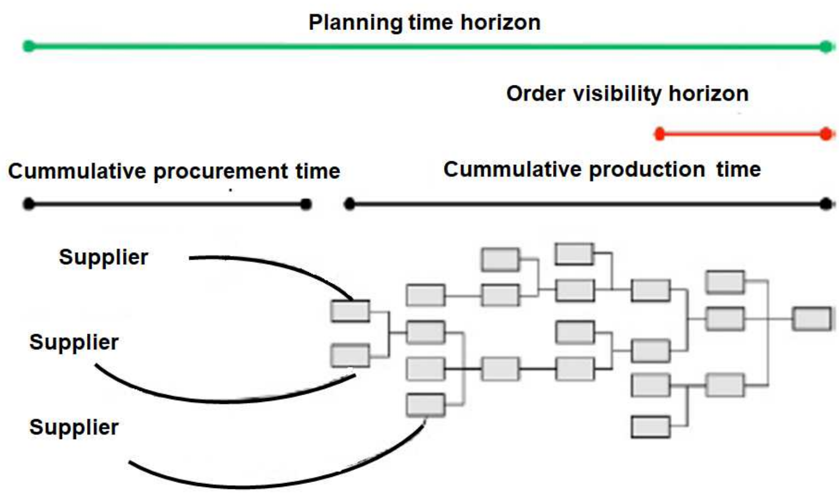

Figure 3 Planning horizon vs. order visibility [19]

2.2 Decoupling points of the logistics chain

The decoupling point helps to reduce system complexity, increase the reliability and manageability of forecasts, and increase capacity utilization, but at the expense of higher inventory costs. Factors that directly affect the location of the disconnection point can be divided into three basic areas:

- market/marketing - specific quantities of the order: demand, frequency, volatility, specific quantities of the customer: prices, quality, promptness, adherence to delivery deadlines, product variability, product customization,
- product - specific quantities of the product: product range, structure, degree of standardization, product design (customer vs. design, environmental and other requirements),
- processes/production - specific quantities: flexibility, speed, throughput, quality, type of production, service.

The suitability of the position of the disconnection point must be assessed in terms of its ability to contribute to the achievement of the company's objectives (Table 1) and in connection with the reflection of the three biggest trends in industrial production:

- co-authorship of the customer - ubiquitous access to information, more intensive competitiveness of the brand, the struggle of the manufacturer and the seller for the customer, stronger voice of the customer, a greater focus on values,
- volatility of demand - predictions are not the biggest problem - the problem is flexibility, mass

customization is expected, B-to-B to B-to-C transition, the balance of capacities by stocks, supply chain segmentation,

- complexity of supply - complexity vs. complexity, the balance between costs and delivery times, risk management challenges, supply chain segmentation, transparency, traceability, simplicity.

The above DDMRP is a methodology that seeks to eliminate the bullwhip effect in the Supply Chain by creating strategic decoupling points along the chain and sizing dynamic reservoirs in them that absorb the variability and volatility of demand. The role of storage buffers within the Supply Chain is to eliminate the impact of demand variability between planning horizons as well as the continuity of supply variability, avoiding the bullwhip effect. A very stable demand signal will be created that has the relevant information needed to effectively manage the Supply Chain, as well as several decoupling points to monitor and ensure that the plan is properly implemented. The result is an agile, yet stable, and durable Supply Chain.

Increased system stability, supported by the right demand signal, means better utilization of production capacity, smaller inventory, lower costs, faster inventory turnover, and thus higher ROA/Return on Assets. DDMRP is a Supply Chain planning and management tool that allows you to respond significantly to the market, reduce delivery time, eliminate demand variability and volatility throughout the Supply Chain, with a significant impact on ROI/Return of Investment. The term DDMRP was originally defined as the ability to know changes in customer requirements and adapt them to planning and production by introducing real-time pulling principles. In 2011 Ptak, C., Smith, CH. founded the Demand Driven Institute, which is focused on the implementation of programs in the field of education and dissemination of DDMRP into industrial practice.

3 Result and discussion

The importance of DDMRP can be explained by comparison with the most commonly used methods of inventory management in industrial practice such as Kanban - as a representative of the lean approach and the mentioned MRP system.

In Table 1 is a comparison of three methods Kanban, MRP II and DDMRP in the horizons of strategy, tactics and operations according to selected criteria.

Tab. 1 Comparison of selected criteria of Kanban, MRP II and DDMRP [19-21]

Horizon/criterium		Method: Kanban	Method: MRP II	Method: DDMRP
Strategy	Long-term planning	Capacity dimensioning, capacity balancing in excess	Strategy aimed at dimensioning and balancing the use of resources	Location and sizing of containers according to PAF/Planned Adjustment Factors
	Flow	Pull	Push (predictions)	Hybrid
	Management strategy	Decentralized planning and production	Centralized planning and production	Hybrid - centralized planning, decentralized production
	Decoupling point	All components / products	All products	Placement of strategic buffers in BOM, creation of decoupling points in the chain
Tactic	Management method	Card sizing, line balancing	MPS/Master Production Schedule	PAF/Planned Adjustment Factor
	Capacity and utilization analysis	Kanban card sizing and balancing	All BOM levels	PAF/Planned Adjustment Factors - checkpoints, increase the efficiency of WIP control
	Demand signal transmission	Kanban circuits	According to BOM	Loops between buffers and MRP integration
	Human resources management	Flexible, real-time allocation	MPS	Flexible, real-time allocation
Operative	Management of buffer	Visual management (circuits, cards)	MRP, scheduling	Demand Driven operating model
	Absorption of demand variability	Short-term flexibility	Safety stock	Buffer status, checkpoints, red zone (protection mechanism with real-time adjustments)
	Priority management	According to WIP in real time	According to the production plan	According to the state of the bins in real time
	Risk management	-	It considers only with anticipated risks	In the NFE/Net Flow Equation, spikes are considered in a limited time
	Visual management	According to the cards	-	According to colour codes

The main problem that MRP, Kanban and DDMRP methods have to deal with the management of resource variability. It can be stated that in a stable environment the results are comparable. However, when reporting demand variability (time or quantity), the MRP system shows its limits. With more significant variability, Kanban also has its limits. The goal of DDMRP is to improve the flexibility of the system at the level of strategic bullwhip effect management, tactical management of WIP/Work in process and WC/Working Capital and resources, and operational management of OTD/On Time Delivery. Strategic modelling of the DDMRP environment allows monitoring the impact of the position of the buffer on the delivery time, allows the determination of the average level of stocks for each buffer and allows analysis of ROI/Return of Investment for each buffer at the decoupling point (taking into account raw material costs). DDMRP is still at the beginning of its development, but nevertheless a number of companies that have implemented this system speak of "(r) evolution in resource and inventory management. There are many examples of world-renowned companies that have implemented DDMRP to increase flexibility in the degree of product customization.

DDMRP combines supply and demand variability into a single buffer, causing instability in lean systems. The lean systems are focused on finding the causes of problems and kaizen, which is missing in DDMRP. DDMRP does not appear as a traction system, as it does not work with current demand, but compares demand on a given day with orders on the way.

4 Conclusions

The complexity of the Supply Chain network structure will have to reflect new approaches and tools that will allow the customer to adapt, customize the product and respond in the time horizon that the customer is willing to accept while waiting for the product. Traditional demand forecasting and demand planning tools are not able to flexibly synchronize supply and demand in this way. This consideration suggests the need to change the way the Supply Chain is managed. The traditional perception of the Supply Chain, focused on the optimization of individual subsystems, is currently not optimal. The work of Smith, D., Smith, CH.: Demand-Driven Performance: The Use of Smart Metrics (2013), which focuses on the definition of supply chains as CAS/complex adaptive systems and states that they are:

- complex - a higher degree of stability is achieved through interactions between actors,
- dynamic - do not stay stable for very long,
- behave non-linearly - even a small change in the initial conditions can lead to larger impulses elsewhere (whip effect),
- adaptive and self-regulatory - that is, they evolve as a result of interaction in the system.

Self-regulation of the logistics and other entities in enterprises will be built on autonomous operation and mutual communication of machines in real-time information flows. Production process will be monitor by sensors and system integration in entire Supply Chain will enable customers to interact with the design and manufacturing process, enhance the machine and equipment availability, shorten the production cycle times, accelerate response to customer requests due to self-regulation of entering transactions. This should result in sustained productivity growth and an increase in return on assets/ROAs.

Acknowledgment

This article was created by implementation of the grant project APVV-17-0258 "Digital engineering elements application in innovation and optimization of production flows", APVV-19-0418 "Intelligent solutions to enhance business innovation capability in the process of transforming them into smart businesses", VEGA 1/0438/20 "Interaction of digital technologies to support software and hardware communication of the advanced production system platform" and KEGA 001TUKE-4/2020 "Modernizing Industrial Engineering education to Develop Existing Training Program Skills in a Specialized Laboratory."

References

[1] FEDORKO, G., VASIL, M., BARTOSOVA, M.: Use of simulation model for measurement of MilkRun system performance, *Open Engineering*, Vol. 9, No. 1, pp. 600-605, 2019. doi:10.1515/eng-2019-0067

[2] STRAKA, M., ROSOVA, A., MALINDZAKOVA, M., KHOURI, S., CULKOVA, K..: Evaluating the Waste Incineration Process for Sustainable Development through Modelling, Logistics, and Simulation, *Polish Journal of Environmental studies*, Vol. 27, No. 6, pp. 2739-2748, 2018. doi:10.15244/pjoes/81062

[3] BINASOVA, V., BUBENIK, P., DULINA, L., DURICA, L., EDL, M., KRAJCOVIC, M., MICIETA, B.: Delegate MASs for Coordination and Control of One-Directional AGV systems: a Proof-of-Concept, *The International Journal of Advanced Manufacturing Technology*, Vol. 94., No. 1-4. pp. 415-431, 2018.

[4] KLOS, S., PATALAS-MALISZEWSKA, J.: The impact of ERP on maintenance management, *Management and Production Engineering Review*, Vol. 4, No. 3, pp. 15-25, 2013.

[5] CHROMJAKOVA, F., BOBAK, R., HRUSECKA, D.: *Production process stability – core assump-tion of INDUSTRY 4.0 concept*, 5th International Conference on Manufacturing, Optimization, Industrial and Material Engineering, pp. 143-154, 2017.

[6] KOBLASA, F, ŠÍROVÁ, E., KRÁLIKOVÁ, R.: The Use of Process Thinking in The Industrial Practice – Preliminary Survey, *The Journal Tehnički vjesnik – Technical Gazette*, Vol. 26, No. 3, 2019. doi:10.17559/TV-20150617135306

[7] SANIUK, S., SAMOLEJOVA, A., SANIUK, A., LENORT, R.: Benefits and barriers of participation in production networks in a metallurgical cluster - research results, *Metalurgija*, Vol. 54, No. 3, pp. 567-570, 2015.

[8] RAJNOHA, R., GALOVA, K., ROZSA, Z.: Measurement of Impact of Selected Industrial Engineering Practices on Companies' Economic Performance, *Inzinerine Ekonomika-Engineering Economics*, Vol. 29, No. 2, pp. 176-187, 2018.
[9] GREGOR, M., HODON, R., BIŇASOVÁ, V., DULINA, Ľ., GAŠO, M.: Design of Simulation-Emulation Logistics System, *MM Science Journal*, Vol. 2018, No. October, pp. 2498-2502, 2018.
[10] KUPEROVA, M., ZATROCHOVA, M.: Logistics conceptions in the production management in small- and medium-sized industrial companies in the Slovak republic, *Toyotarity,* Vol. 2014, pp.135-146, 2014.
[11] GREGOR, T., KRAJCOVIC, M., WIECEK, D.: *Smart Connected Logistics*, In Procedia Engineering. Vol. 192, Transcom 2017 12th International Scientific Conference of Young Scientists on Sustainable, Modern and Safe Transport. High Tatras, Grand Hotel Bellevue, Slovakia, pp. 265-270, 2017.
[12] ROSOVÁ, A.: The system of indicators of distribution logistics, transport logistics and material flow as a tool of controlling in logistics enterpise, *Acta Montanistica Slovaca*, Vol. 15, No. 1, pp. 67-72, 2010.
[13] FURMANN, R., FURMANNOVÁ, B.: *Logistics and digital twin*, InvEnt 2017: Industrial Engineering – Invention for Enterprise, Wydawnictwo Fundacji Centrum Nowych Technologii, Szczyrk, PL, 2017.
[14] STRAKA, M.: Alfa, a.s. distribution logistics system, *Acta Montanistica Slovaca*, Vol. 15, No. 1, pp. 34-43, 2010.
[15] SCHRAUF, S., BERTTRAM, P.: Industry 4.0 & How digitalization makes the supply chain more efficient, agile, and customer-focused [Online], Available: https://www.strategyand.pwc.com/gx/en/insights/2016/industry-4-digitization/industry40.pdf [20 Feb 2020], 2016.
[16] WICHER, P., STAŠ, D., KARKULA, M., LENORT, R., BESTA, P.: A computer simulation-based analysis of supply chains resilience in industrial environment, *Metalurgija*, Vol. 54, No. 4, 2015.
[17] STRAKA, M., MALINDZAK, D.: Algorithms of capacity balancing of printing machineries for Alfa Foils, a.s. planning system, *Acta Montanistica Slovaca*, Vol. 14, No. 1, pp. 98-102, 2009.
[18] GRZNAR, P., GREGOR, M., MOZOL, S., KRAJCOVIC, M., DULINA, L., GASO, M., MAJOR, M.: A System to Determine the Optimal Work-in-Progress Inventory Stored in Interoperation Manu-facturing Buffers, *Sustainability*, Vol. 11, No. 14, pp. 1-36, 2019. doi:10.3390/su11143949
[19] PTAK, C., SMITH, C.: *Demand Driven Material Requirements Planning (DDMRP)*, Industrial Press Inc., 2016.
[20] IHME, M., STRATTON, R.: *Evaluating Demand Driven MRP: a case based simulated study*, International Conference of the European Operations Management Association, Neuchatel, Switzerland, [Online], Available: http://irep.ntu.ac.uk/id/eprint/26668/1/PubSub4006_Stratton.pdf [20 March 2020], 2015.
[21] GUPTA, M. C.: Comparing TOC with MRP and JIT: a literature review, *International Journal of Production Research* Vol. 47. No. 13, [Online], Available: https://www.researchgate.net/profile/Mahesh_Gupta8/publication/245331485_Comparing_TOC_with_MRP_and_JIT_a_literature_review/links/573e125f08ae9ace84112cc4/Comparing-TOC-with-MRP-and-JIT-a-literature-review.pdf, [20 March 2020], 2009.

Review process

Single-blind peer review process.