Optimisation of Logistics Processes Using Simulation Tools

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INTRODUCTION

Efficient production management is based on the basic principles of logistics organisation. In every enterprise in which product production processes are carried out, it is necessary to design, efficient implementation and maintenance of a system that should meet all the requirements set for it in terms of controlling production flow. Any activities that apparently do not seem to belong to the elements of the production control system are actually included in them. Such a phenomenon can be observed in the case of micro, small and medium enterprises or those whose organisation is not at a high level – the functions of the control system are often performed intuitively. Therefore, the use of simulation programmes significantly facilitates the management of processes, including logistics.

All activities related to supplying the production process with appropriate raw materials, semi-finished products, auxiliary materials, parts from purchase, transfer of finished products and distribution. It should be properly organised to ensure access to all materials, as well as components of a given product during the implementation of a given order of semi-finished products to the sales warehouse are issues that include logistics. In production logistics, it is important that it combines supply logistics with distribution logistics. Production logistics performs management functions such as planning, motivating, organising, controlling, and is also one of the basic elements of the enterprise's operation.

Planning in production logistics is an integrated, continuous, systemic process based on continuous learning.

The basic planning features include continuity, which is associated with the update of production plans and integration understood as the integration of intentions and goals. An additional element is to ensure safety in enterprises and this is an important element in their functioning due to the occurrence of accidents at work. These events are a current problem for many industrial enterprises due to the social and economic costs of occurring events. Therefore,

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employers should take all actions aimed at improving safety in the workplace (Małysa, 2019).

The idea of planning is to make decisions regarding elements of control processes that are outside the planning system and belong to its environment. Production planning consists in determining the range of products needed to produce the quantity of finished products specified in accordance with the plan, as well as staggering these products in production in such a way as to ensure the implementation of sales plans, achieving the assumed level of customer service, productivity and profit.

Supply chain is one of the most important elements of logistics. It is a network of organizations involved in processes and activities. This network is associated with suppliers and customers, and processes and activities create value in the form of products and services that are delivered to consumers. The supply chain is created in every enterprise as a result of combining the activities of supply, production and distribution zones. Chain management requires the development of tools that enable stream identification and improvement. The supply chain is one of the most popular forms of system solutions in logistics. It is characterised by the following features: process, structure and goals; where the process includes the subject of the flow, the structure relates to the subject structure, and the objectives cover the functional scope, and also include areas of cooperation of all participating entities.

The nature of logistics decisions made in the management process depends on the management level. There are two levels of decision in the area of production, which include strategic and operational decisions. Strategic decisions are characterized by their long-term nature; they are long-term and their goal is effectiveness (they can answer the question: ‘Do we do the right things?’). They have a project character, they prepare the system to operate in the operational area. They are developed at the stage of setting production goals and strategies. In turn, operational decisions are medium- and short-term decisions that are characterised by efficiency (question: ‘Do we do them properly?’). They are more executive and focus on the effectiveness of performed operations. Both levels of decisions are integrated with each other. Well-developed both decision levels result in a satisfactory operation process.

PRODUCTION LOGISTICS

Production logistics is one of the functions of logistics. Production is one of the main and most important tasks of the production system. As a result, new utility values are created. Products are created by adapting and transforming work items with the participation of labour resources and human labour (Szymonik, 2012)

According to H. Ch. Pfohl production logistics are activities related to (Pfohl H. Ch. 2001):

- supplying the production process with appropriate raw materials, semi-finished products, auxiliary and consumable materials, as well as parts from the purchase,
- delivery of finished products and semi-finished products to the sales warehouse.

Seven basic processes can be distinguished in production logistics. These include product development, sales, order processing, supply, production, distribution and after-sales service. The product development process takes place from recognising the needs of the market to the moment the product is introduced to the market. Sales are the moment of indicating potential customers until the customer makes a purchase decision. The order execution process is at the stage of placing the order by the customer to receive payment by the company. Purchasing is the moment of identifying the demand for raw materials and materials, their receipt and settlement of obligations towards the supplier. Production occurs from the moment of recognising the demand for the product until its implementation. Distribution covers the moment the finished product is manufactured in the enterprise until it is delivered to the customer. The customer retention from the time of sale belongs to sales service tasks (Bendkowski 2013).

The correct definition of the logistics process requires the indication of the person managing the process, determining the resources necessary to initiate the process, assigning the rights to control and control the process, assigning the necessary contractors and means to implement, determining the factors stimulating or hindering implementation, potential units that may be recipients, and additional potential desired final results, as well as actions to respond to unplanned deviations.

Production management requires identifying the following elements of the logistics process (Bendkowski 2013):

- collecting demand information, e.g. demand forecasts,
- customer acquisition – directing the market offer and product promotion to customers known to the manufacturer, e.g. wholesalers, potential customers and anonymous customers to encourage them to buy,
- production planning – determining the demand for raw materials, materials that should be bought from the supplier,
- purchases – searching and choosing suppliers, placing orders and purchase transaction,
- internal production and distribution – to own distribution centres,
- supply – organisation of supply chains, including transport as well as taking delivery and storage,
- distribution to the customer.

In order to integrate the flow of materials from supply through production to distribution, the production company uses logistic strategies. This is done inside the production system. The integration of material flows is aimed at increasing efficiency and reducing costs by minimising the time of product and material flows, optimising inventory, providing the highest level of customer service and the lowest level of global costs in the logistics channel. Table 1 presents the assumptions and applications of logistics strategies based on the concepts of JIT, inventory management, integrated supply chain, MRP/MRP2, agile and lean manufacturing that help achieve the above-mentioned effects (Fertsch M., Cyplik P., Hadaś Ł. 2010).

Table 1 Assumptions and implementation of logistic strategies

Strategy	Strategy assumption	Strategy implementation
Supplies management	Inventories are inextricably linked to production and trade activities; inventory creation results from uncertainty of forecasts, economic considerations, material flow characteristics, inventory as an integral part of material flow.	In any enterprise, inventory depends on the enterprise's individual determination of the ordering system or batch size calculation method, inventory maintenance requires appropriate infrastructure, adequate storage space and handling equipment, financial resources and information support.
Just in Time	Shaping relationships with suppliers and customers and relations with employees, eliminating everything that does not add the value of a product or service to the final recipient, efficient use of resources, focusing the enterprise on satisfying customer needs, reducing inventory, increasing flexibility, partner cooperation with suppliers and improving quality	as well as rhythmicity and repeatability of production, control of the production of established products manufactured in large series, relations with suppliers based on partnership, close location of cooperating suppliers, timeliness of deliveries is very important, it is necessary for this machinery to keep this principle.
MRP	Uses the product structure, inventory data, main schedule, data on the size of the delivery batch and delivery cycles, allows you to control individual stages of production, allows faster response to changes in the environment, it is necessary to exchange information between the supplier and the recipient.	Usually used for complex products, consisting of many components, knowledge about inventory is necessary, it requires the use of advanced computer technology – IT and information facilities.
MRP II	Developing the MRP concept, planning production resources, based on the concept of adjusting the size of resources to changing demand, requires IT support, uses forecast demand, customer orders, product structure, production capacity, positions and work calendars, as well as standard costs.	It requires a large information base supported by computer systems, used for complex products with a large number of sub-assemblies and parts for which demand can be determined, allows you to base relationships with suppliers on a partnership basis.
Supply chain strategy	Comprehensive treatment of the flow of goods in the supply chain, joint problem solving, action strategies for all participants in the chain, organisation of operations, decision making, resource management, the goal is to gain a	Possible when the knowledge of partners' activities, their competences, specialisations, reliability, etc. is known, a supply chain created to produce repetitive goods with high demand, creating an integrated supply chain to

	competitive advantage by all participants in the supply chain by meeting the needs of final customers	achieve competitive advantage and better market position, a partnership between participants in the supply chain, the need for computer support.
‘Lean’ production	Continuous reduction of waste, elimination of activities that do not add value, building a value chain, engaging the least number of people, time, inventory in the production process that is implemented effectively and generates the lowest cost	Focusing the company's activity on its basic function, a strategy that works in repetitive production, requires a lot of employee involvement.
‘Agile’ production	Developing, prospering in a competitive environment, ability to respond quickly to changing market conditions, customer focus, quick response to his needs, readiness to change, individual products in accordance with customer requirements, the customer is included in the design process and manufacturing process	Application in small scale or unit production for highly complex products, proper organisation of processes is required – technological specialisation of nests forming the production structure.

Source: own elaboration on the basis of (Fertsch M., Cyplik P., Hadaś Ł. 2010 and. Kuczyńska-Chałada, M. and Furman, J. 2016).

One of the important elements of logistics is the supply chain, which is a network of entities involved in various processes and activities. This network is associated with suppliers and recipients, and processes and activities create values in form of products and services that are delivered to final consumers (Christopher 2000 and Szymonik 2011).

SIMULATION TOOLS SUPPORTING PRODUCTION LOGISTICS

Increasing requirements of production quality and lowering the costs of introducing new technologies force enterprises to use increasingly advanced tools enabling virtual production planning. Simulation is a technique for solving problems, involving the use of appropriate virtual models (Zdanowicz 2006).

The main advantages of visual-interactive simulation include:

- better understanding of the model,
- easier model verification and validation,
- the possibility of interactive experimentation,
- improved presentation and interpretation of results,
- improved communication with the model,
- adaptation for potential use in problem solving groups.

Required features of modern simulation programmes are:

- generating random numbers from a homogeneous probability distribution
- generating random values from a specified probability distribution
- progressing simulation time
- determination of subsequent results and current control of the simulation code

- data collection and analysis
- reporting results
- detection of surroundings errors.

Generally, simulation and modeling software can be divided into three main groups:

- spreadsheets
- general-purpose software languages
- professional software.

Increasing competition resulting from the use of production automation to increase productivity has increased the complexity of production systems that can only be analysed by simulation. The widespread use of computerisation on the global scale and the reduction of software and hardware prices have contributed to the development of simulation software. It can be said that simulation is a helpful technology that is increasingly used to increase system performance by providing information to make the best decisions. The development of multimedia techniques allowing the animation of production systems has contributed to a better understanding of simulation theory by managers and people not related to simulation and modeling.

PRODUCTION IMPROVEMENT WITH THE FLEXSIM PROGRAMME

Identification of problems in the process

The analysis concerned the distribution of logistics chain of the cold chain. This cenre usually has the functions of collecting and distributing, connecting, transporting at low temperature, cooling, sorting, loading and unloading, transferring information. The analysis covered a period of three months (February-May 2020).

The logistics centre's internal cold chain operating process has six basic steps, including ordering, receiving goods, processing, storage, sorting and distribution.

The cold chain distribution centre covers specific areas:

a. The collection area includes unloading, inspection and storage of goods. Fruit and vegetables have a short shelf life.
b. The marketing and processing area mainly concerns fruit and vegetables from the place of collection (washing, partition wall, packaging, etc.).
c. The counting and sorting area mainly sorts and packs fruit and vegetables.
d. The storage area contains cooling and freezing.
e. Distribution and delivery area: employees should send fruit and vegetables according to customers according to a specific route and certain time limits.

Aims of simulation

Because the goods from the cold chain have perishable features, i.e. a short cooling cycle, etc. two simulations have been made regarding the transport turnover of fruit and vegetables, and unloading capacity at the distribution centre (employee performance, machinery) to find a bottleneck of the operating system and improve the balance of the fruit's operational process and the distribution centre of the vegetable cold chain.

Data collecting

Collecting data, the simulation uses the variable t (day) ($t \geq 0$) represents the refresh time of fruits and vegetables. There is a classification of fruit and vegetables into three types according to variable t.

Types of fruit and vegetables for simulation include a short refreshment time (refresh time $t < 3$), refrigeration products ($3 \leq t \leq 7$) and frozen goods ($3 \leq t \leq 7$). The arrival time of fruit and vegetables is consistent with the Poisson distribution (10.1) (min). Goods reach 4000 per batch and the average weight is 1000 kg per batch. The arrival and processing time for fruit and vegetables is (3.5) (min). The counting and sorting area is (1.3) (min), the distribution and delivery area (5,10) (min).

Operation parameters and simulation elements

- Simulation time: the unit simulation time is 1 min.
- Simulation work hours as 8/day (480 min).

Figure 1 shows a simulation model of a fruit and vegetable distribution centre.

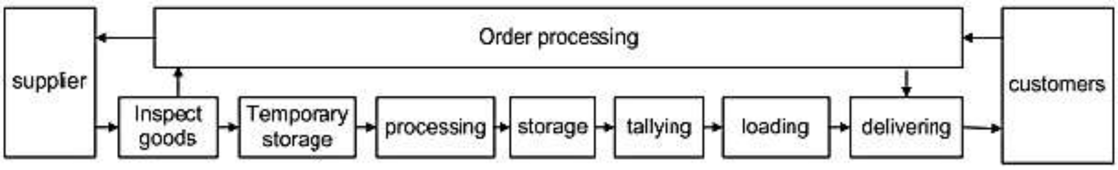

Fig. 1 Process of othe fruit and vegetable distribution centre operating.

Source: own elaboration

Before performing the simulation, the distribution centre assumptions should be defined:

1. Fruit and vegetables are sent for distribution according to the agreed lot and arrival time.
2. Fruit and vegetables arrive continuously during the simulation.
3. The weight of fruit and vegetables is equal.
4. The refreshment time is not the same for different fruits and vegetables and the maximum refreshment is 7 days.
5. The simulation module covers the collection area, circulation and processing area, tallying and sorting, storage, distribution and delivery. These areas consist of specific operational processes.

RESULTS ANALYSIS

The simulation model allowed to obtain statistics of conveyor work status (Table 2) and employee work status statistics (Table 3).

Table 2 shows the processor 13 bottleneck (area and sort processor) is 39.94%. The analysis shows that the performance of the processor 13 is very low.

Table 2 Statistics of the state of machine work

Object	Busy%	Idle%	Block%
Processor 19	69.87	30.13	0.00
Processor 9	79.44	20.56	0.00
Processor 13	39.94	60.06	0.00
Processor 24	61.95	16.90	0.00

Source: own elaboration

Table 3 shows that the transport speed of conveyor 19, conveyor 22 and conveyor 25 is 68.1%, 84% and 28.6% respectively, however, the speed of conveyor 25 (sorting and supplying conveyor) is only 28.60%, and the blocking rate of the conveyor 25 is 38.60%. The capacity of the conveyor 25 is very low.

Table 3 Statistics of conveyor operation status

Object	Conveying%	Empty%	Block%
Conveyor 19	68.10	13.20	18.70
Conveyor 22	84.00	10.00	0.00
Conveyor 25	28.60	32.80	38.60

Source: own elaboration

Table 4 shows that the turnover ratio of position 1 is 68.10%; the turnover ratio for position 2 is 10.35%; position 3 turnover ratio is 13.04%.

Table 4 Statistics of input and output elements

Object	Input	Output	Turnover rate
Item 1	47	32	68.10
Item 2	29	3	10.35
Item 3	23	3	13.04
Total	99	38	38.38

Source: own elaboration

The total turnover ratio is 38.38%.That means that the commodity turnover ratio is extremely low, and the distribution centre's operational process has problems with delay and bottleneck. The above analysis of the simulation results shows that the degree of use of equipment and employees is too low.

OPTIMISATION OF THE OPERATIONAL PROCESS

1. Backlog of goods from counting and sorting, where the bottleneck is the reduction of vehicle transport. The solution is to increase the number of vehicles.
2. Equipment performance in distribution and the delivery area is very low. The reason is that the machine is idle for a long time. The solution is to increase stopping areas.

3. Operator idle 29 level (warehouse space operator) is high and the forklift can replace operator 29 to solve this problem.

Optimised distribution centre – simulation modeling

Table 5 shows the differences between the two simulations (Fig. 2).

Table 5 Results of the simulation

Evaluation index	Name of entity	Before optimization %	After optimization %	Contrast %
Turnover rate	Item 1	68.10	91.43	23.33
	Item 2	10.35	88.24	77.89
	Item 3	13.04	87.50	74.46
Use efficiency of processors	Processor 19	69.87	73.45	3.58
	Processor 9	79.44	81.08	1.64
	Processor 13	39.94	43.49	5.55
	Processor 29	61.95	74.91	12.96
	Processor 30	—	67.88	—
Use rate of transporter	Transporter 22	78.80	78.80	0.00
	Transporter 20	40.90	40.90	0.00
Use rate of ASRSvehicle	ASRSvehicle 22	90.10	80.20	-9.90
	ASRSvehicle 29	—	78.60	—
Use rate of operators	Operator 24	92.20	91.10	-1.10
	Operator 29	3.70	—	—
	Operator 28	43.10	74.60	31.50
Use rate of conveyors	Conveyor 19	68.10	84.80	16.70
	Conveyor 22	84.00	86.99	2.99
	Conveyor 25	28.60	27.40	-1.20

Source: own elaboration

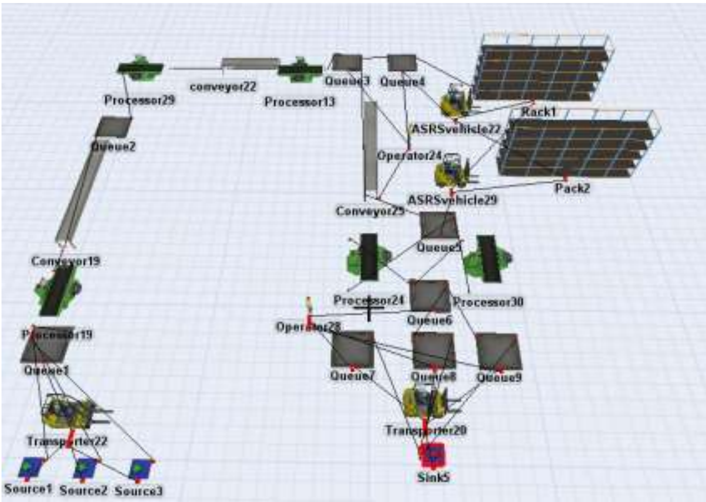

Fig. 2 Optimised simulation model

After optimising the turnover system, the rate per day for all types of fruit and vegetables exceeds 87%. The turnover index for position 1 (refreshment time $t < 3$) reaches 91.43%, which means an improvement of 23.33%; the turnover index in position 2 (refrigerated goods $3 \le t \le 7$) reaches 88.24%; item 3 turnover index (frozen goods $3 \le t \le 7$) reaches 87.5%.

At the same time, the rate of use of equipment in the distribution centre is higher. The use of employee index 3 (operator 28) is improved by 31.5%; the speed of using conveyor 19 (receiving conveyor) is improved by 16.70%; the utilisation of processor speed 29 in distribution and delivery area is improved by 12.96%.

CONCLUSION

Using the simulation, data on resources used was obtained, i.e. equipment, employees. The analysis showed at what stage of the process the bottleneck and unused resources occurred.

If the production logistics is properly organized, it provides access to all materials and components of a given product during the implementation of a specific order. It ensures continuity and rhythm of production after its launch and convenient conditions for the use of modern internal transport (Bendkowski, Matusek 2013).

REFERENCES

Małysa, T. (2019) Work safety during usage, repair and maintenance of machines – a review of work safety in the aspect of accident at work. In: New Trends in Production Engineering, ed. T. Frączek. Sciendo, vol. 2, iss. 2, pp 151-161. Available at: https://doi.org/10.2478/ntpe-2019-0080. [Accessed 01 Jun. 2020].

Szymonik A. (2012) Logistyka produkcji. Difin. Warszawa. p.35

Pfohl H. Ch. (2001) Systemy logistyczne: podstawy organizacji i zarządzania. Instytut Logistyki i Magazynowania. Poznań.p. 78

Bendkowski J. (2013). Logistyka jako strategia zarządzania produkcją. Zeszyty Naukowe Politechniki Śląskiej. Gliwice. z. 63. p. 7-21

Fertsch M., Cyplik P., Hadaś Ł. (2010) Logistyka produkcji. Teoria i praktyka. Instytut Logistyki i Magazynowania. Poznań.

Kuczyńska-Chałada, M. and Furman, J. (2016). The process of improvement with the application of lean manufacturing in a steel company. In: METAL 2016: 25th Anniversary International Conference on Metallurgy and Materials, Ostrava: Tanger, p. 1895.

Christopher M. (2000) Logistyka i zarządzani łańcuchem dostaw. Polskie Centrum Doradztwa Logistycznego. Warszawa.

Szymonik A. (2011) Logistyka i zarządzanie łańcuchem dostaw część 2. Difin Warszawa.

Szymonik A. (2011) Logistyka i zarządzanie łańcuchem dostaw część 1. Difin Warszawa.

Zdanowicz R. (2006) Pomiary Automatyka Robotyka 1/2006, Selection of software for modeling and simulation of manufacturing processes

Bendkowski, J. and Matusek, M. (2013). Logistyka produkcji. Praktyczne aspekty, Volume 2, Gliwice: Wyd. Politechniki Śląskiej, p. 35.

Abstract: Optimization of production logistics processes through the use of simulation tools brings a lot of benefits to a production company, and thus significantly reduces production costs. Increasing competition resulting from the use of production automation to increase productivity has increased the complexity of production systems that can only be analysed by simulation. Production logistics performs management functions such as planning, motivating, organising and controlling. It does not deal with technological processes, but the organisation of physical delivery and displacement of components and information in the system. An important feature of production logistics is combining supply logistics with distribution logistics. If the production logistics is properly organised, it provides access to all materials and components of a given product during the implementation of a specific order. Simulation tools ensure continuity and rhythm of production after it is started, as well as convenient conditions for using modern internal transport. The article presents the Flexsim simulation tool, which was used to improve production logistics in the studied enterprise. The programme also contributed as an opportunity to improve and shorten production cycles, maintain optimal inventories, select packaging and logistics units, as well as the ability to use automatic identification of raw materials, materials or semi-finished products.

Keywords: production logistics, simulation tools, Flexsim