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UNDERSTANDING THE PURCHASING PORTFOLIO MODEL – A JUST-IN-SEQUENCE APPROACH INCREASING MANUFACTURING EFFICIENCY

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Just-in-sequence supply solutions are highly searched problems of the scheduling the manufacturing and logistics resources. The cost reduction, efficiency and capacity utilization are based on the controlled and designed parameters of the participant supply processes and services. The optimization of the supply process is unavoidable in the development processes of the supply chain' inventory activities along the logistic operations and other services. The aim of this article is to measure the efficiency of the supply chain's inventory activities in manufacturing technology processes. Based on the results of the application of our ABC-XYZ model approach to defines the importance of product values in the inventory management systems. Based on just-in-sequence strategy, the case study and computational results validate the matrix model and evaluates its efforts to renewing the efficiency of manufacturing and delivery processes in inventory strategies.

Key words: logistics, manufacturing technology, purchasing, procurement

INTRODUCTION

Manufacturing and service provider's companies are focused to be competitive in the industry and market areas, especially in the field of automotive industry and mechatronic assembly processes.

In a globalized world we can ask that question which companies able to apply the development of supply chain design and control solutions in their processes and services?

These mentioned processes are included several logistic functional tiers, where these levels have a connection with each other. These systems usually go through via regular process steps, which are already known. The manufacturing processes contain the following part of operational logistic areas: purchasing, manufacturing, customers and inverse processes.

The aim of this paper is to identify challenges of just-in-sequence supply (JIS) in the case of interconnected systems. The second goal of this paper is to define mathematical model to optimize the requested sequence of the final product among the just-in-sequence supply chain.

Due to the large numbers of research on the related streams the most relevant scientific results must be summarized before elaborating different decision model, proposing algorithm and providing conceptual solutions. This paper is organized as follows: Literature review can summarize the most relevant scientific results related to the strategies of just-in-sequence supply chain. Second part of literature review shows the developing potentials of the Just-in-sequence supply chain strategies. Purchasing portfolio designing with ABC-XYZ analysis describes an optimal Purchasing portfolio designing with ABC-XYZ analysis. Case study and computational results demonstrates the numerical analysis of the application. Conclusions and future research directions are presented in Conclusions.

LITERATURE REVIEW

There exist a huge number of articles what related to just-in-sequence supply in manufacturing processes and services. To make methodology of structured literature review and define conceptual framework for the connection between this research work and the researcher, we are focusing on the most relevant results to analyze the following questions:

- search for scientific articles in selected sources (Scopus, ResearchGate, Google Scholar and Science Direct),
- select out the most relevant articles by reading the abstract and identify the main topic,
- define a methodology to analyze the relevant articles,
- describe the main scientific results and identify the scientific gaps and bottlenecks [1].

At first, the relevant terms were specified. It is a crucial phase of the integrated review, because there are found excellent review articles in the field of just-in-sequence in possibility of increasing manufacturing processes and we applied the presented methodology. We used the following keyword to search in the Scopus database: "just-in-sequence". Initially, 89 articles were identified. In the following step, this list was reduced to 41 articles selecting journal articles only. We excluded articles, which direction did not find any interest and cannot be addressed the operation management aspects of decision making in just-in-sequence manufacturing processes. After this reduction, we got 28 articles. We added 3 other most relevant articles selected through separated search in 2020, so the final list for classification and evaluation from the point of view scientific results include 31 articles.

Figure 1 shows these articles considering 10 subject areas. This classification shows most of interest in engineering, business, management, and computer sciences. Our search was conducted in September 2020; therefore, new articles may have been published since then.

As Figure 2 demonstrates the decision making in just-in-sequence processes has been researched in the past years. In the past, the first article was published in 1997 in this field and it was concentrating on the operational management [2]. The number of published papers show the importance and the potentials of that research field in the last 10 years.

Figure 3 shows the distribution of the most frequently used keywords is depicted. As the keywords show, the aspects

of JIT/JIS supply processes in automotive manufacturing is based on support these systems and optimization possibilities to describe uncertainties and behaviour.

Since our study embraces three related research streams, namely just-in-sequence supply, supply chain management and its development methods, we provide a brief review on each stream before to present our approach.

The just-in-time (JIT) and just-in-sequence challenges define different aspects of the solutions such as (1) build the concepts to figure out logistics problems, (2) manage the requirements of a changing customers' demands from supply chain, (3) change industrial policies for efficient production and movement of goods and services. In fact, the impact of JIT/JIS strategies have also



Figure 1: Classification of articles considering subject areas based on search in Scopus database using "just-in-sequence" keyword (without refined results)

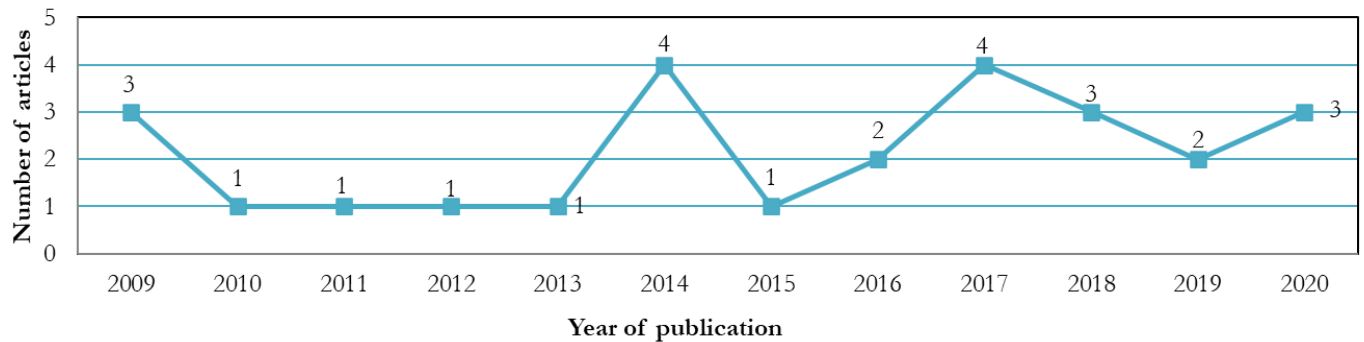


Figure 2: Classification of articles by year of articles



Figure 3: Classification of articles considering the used keywords

been the subject of (4) restructure the manufacturing and logistic processes, (5) scheduling efficiently of capacity utilization and (6) increasing supply chain management (SCM). The objective function is the minimalization of the operational costs among the whole supply chain's material flows. According to the literature, there is economics competition to fulfill the market's demands. It can be achieved by minimize costs in-plant systems, develop the responses about the customer requests and reduce in-plant lead time.

The renewing supply chain is related to hyperconnected global supply chains require up-to-date modern and new supply chain strategies, which are able to support the better understanding between each other of the certain sectors. This stream is notable in two different area. The first is addressed to the manufacturing industrial companies, especially in the fields of automotive industry. The second is dedicated to the final product delivery services including best practices and innovative solutions to enhance the competitiveness.

One of the most important challenge of the automotive industry and the mechatronic assembly processes is the implementation of Industry 4.0 solutions within just-in-sequence supply chain developments. The scheduling of the technological and logistic resources has become a key focus for the logistics market, especially in the field of just-in-sequence supply chain. The manufacturing companies and the third-party logistic (3PL) are connected as a multi-sequenced network, which are increasing more complex operational environment of the supply chain's processes, especially in manufacturing systems. These are focusing on the effect of Just-in-sequence on the fluidity of these processes [3].

Just-in-sequence strategies are also mentioned as a reinterpretation of Just-in-time concept. The integration of participants as a network conduce to the implementation of standards and the realization of supply strategies like just-in-time or just-in-sequence strategies [4]. These concepts help to renew the processes and control the services of manufacturing based on the supply chain: develop the traditional supply chain processes, adapt modern and innovative methods in renewing manufacturing and delivery processes and provisioning of intermediate goods [5], increase better quality of their services, reduce emissions, scheduling and delivering the requested goods to serve out the customers at the lowest cost through the material flows [6], highlights the main features of each system with respect to logistics activities [7] by planning their sources [8].

The aims of Toyota production systems are the followings: serving good quality products on low costs of operation and satisfying customer request based on decision model [9]. BMW car manufacture is also implemented the just-in-sequence production into warehouse [10] and allocate time slots to transport shippers [11]. As the practical application has shown that the audit makes possible to improve the communication between all participants and the process improvement for enabling part-

nership-based optimization [12]. This strategy is one of the most popular lean method. There are several advantages such as controlling costs, reducing risk of supply chain [13], stabilizing the work-in-progress inventories along interorganizational interfaces in production networks and supporting third-party logistics (3PL) [14].

Design of Just-in-sequence is researched from the view of supply chain solutions. Just-in-sequence supply include several advantages of the manufacturing and supplier processes in the followings: automotive industry has been encouraged for the following tasks [15]: to enabling the smallest lot numbers to be produced at a minimal stock level [16], supermarkets and decentralized logistic areas [17], improving the just-in-sequence operation of an automotive inbound logistic process [18] and services by applying RFID [19]. The systems work smoothly better and provides comprehensive assurance in the installation of the wiring harnesses [20].

Different methods can demonstrate the key connection between improvements in supply chain performance and enhanced economic development [21]. These solutions are also available in core business, where the enterprise applications support the whole business process. Multi-agent system framework is developed to manage dynamic production flows [22].

Several books and articles have been published which demonstrates the potential Industry 4.0 implications in the context of Just-in-Time/Just-in-Sequence and cross-company Kanban systems in a precise manner [23], propose the mixing the discrete event and agent based solution [24].

Mathematical and systematic models can find in the scientific literature, which are constructed to find the supporting way of the decisions with the just-in-sequence supply philosophy. The companies are committed to increase their supply processes through maximize capacities and reduce the cost of the manufacturing and servicing processes.

Suppliers can fulfill just-in-sequence demands, because they can restore the original sequence by using mixed-integer linear programming formulation [25].

There are several available methods including algorithms (used genetic, particle, ant colony, and fuzzy bi-objective), model are to apply heuristic optimization to analyze just-in-sequence supply chain by developing algorithm-based solutions. One of algorithm is a flower pollination-based algorithm, because its function of CEC benchmarking shows the suitability to solve NP-hard problems [26].

Simulation provides an ideal environment for check the solutions. Researcher can be able to analysis an imitation of the real process and provides better schedules solutions for quality developing near optimal calculations. The complex supply chain and its networks led to an increased usage of simulation solutions. The proposed methods can be simulated in the real environment of the problem solving via modified metaheuristic bee col-

Table 1: Costs for evaluating supply strategies (* - lowest cost, ***** - highest cost)

Costs	Traditional	Consignment	JIT	JIS
Manufacturing costs: Assembly costs	***	***	****	*****
Parts delivery to the storage. Preparing for production (supermarket). Serving out assembly line – based on the selected inventory strategies. Production. Output storage.				
Warehousing costs	***	*****	***	****
Infrastructural. HR. Material handling. Physical inventory costs. Value inventory costs.				
Ordering costs	**	***	****	*****
External. Internal.				
Delivery costs	***	***	****	*****
Manufacturing. Supply chain.				
Replacement costs	***	****	***	*****
Replaceable activities. Irreplaceable consequences.				
Natural resources costs: Depletion costs are hidden to the cost of each product.	**	**	****	*****
Environmental attitudes. Climate change. Noble gases deposition. Land usage. Degradation.				

ony algorithm to show the highlights of the demonstration of feasibility and effectiveness [27] and developed to efficiently structure the simulation model into several separate federates as a building block system for large supply-chain models [28]. In fact, the proposal solutions can be validated through simulations. The simulation of the POLCA system show the potential of coordination possibility in its production flows [29]. Other simulation tool, called Tecnomatix Plant Simulation enables to create digital models of the logistic systems to characterized and analyzed the optimization of the systems [30].

More than 45% of the related articles were published in the last 4 years. This result indicates the scientific potential of this research field including the problems of Just-in-sequence supply in inplant and external logistic systems. Several studies and articles have been published which address Just-in-sequence to resynchronize the material flow through performance and efficiency [31]. The literature sources show the impact of desing and optimisation of manufacturing related processes, like purchasing, procurement and warehousing on the efficiency and availability of manufacturing [32-33].

PURCHASING PORTFOLIO DESIGNING WITH ABC-XYZ ANALYSIS

The ABC analysis is one of the most important tools to optimize inventory, where the volumes are taken into consideration. The ABC analysis has a good performance in the case of low uncertainties. In the case of measurable uncertainties of sales the rate of uncertainties has to be taken into consideration. This aspect adds a new dimension to the ABC analysis and this method is the ABC-XYZ analysis, which focuses on both volumes and their uncertainties (Figure 4).

The efficiency of the stocks can be examined by mathematic and heuristic methods. We define the following costs to evaluate and compare the traditional and JIT/

JIS supply strategies. Table 1. represents the following the impact of parameters: (I.) The natural objective functions include all costs of the obtaining and replacing natural resources processes; (II.) The cost-based objective functions are related to logistic operations, additional and other service costs in supply chain’s inventory activities.

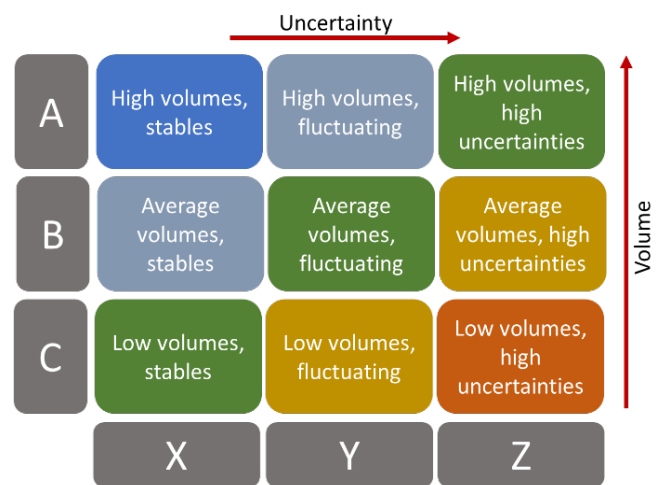


Figure 4: The structure of an ABC-XYZ matrix

The objective functions of the problems describe the minimization of the inventory costs of supply chain: manufacturing, warehousing, ordering, delivery, replacement and natural costs:

$$C = \sum C_{man} + C_{ware} + C_{ord} + C_{del} + C_{repl} + C_{nat} \rightarrow \min \quad (1)$$

Where:

C_{man} = Manufacturing costs [EUR],

C_{ware} = Warehousing costs [EUR],

C_{ord} = Ordering costs [EUR],

C_{del} = Delivery costs [EUR],

C_{repl} = Replacement costs [EUR],

C_{nat} = Cost of natural resources [EUR].

The application of the ABC-XYZ classification defines the products of different importance. Table 2. represents our matrix model approach to classify the inventory strategies (JIS, JIT, Consignment, Traditional) along the product activities and variables into nine different classes (AX, ..., CZ).

Table 2: ABC-XYZ classification model for supply strategies

ABC-XYZ Classification	A	B	C
X	JIS		Traditional
Y	JIT		
Z	Consignment		

The ABC analysis can be used for several levels, where the selected inventory products are categorized into groups according to relative frequency of value and each group develop differentiated inventory management systems. In the XYZ analysis, products can be classified based on usage fluctuations and forecast accuracy.

CASE STUDY AND COMPUTATIONAL RESULTS

Based on the proposed approach, we have analyzed our fictive company's products (set of 1000 pieces) by using ABC-XYZ analysis to classify and arrange them in terms of achieving business goals (Eq. 1).

First, we have defined the following inventory criteria for group formation (ABC):

- each item's unit cost,
- each item's unit volume,
- annual volume,
- annual cost of usage.

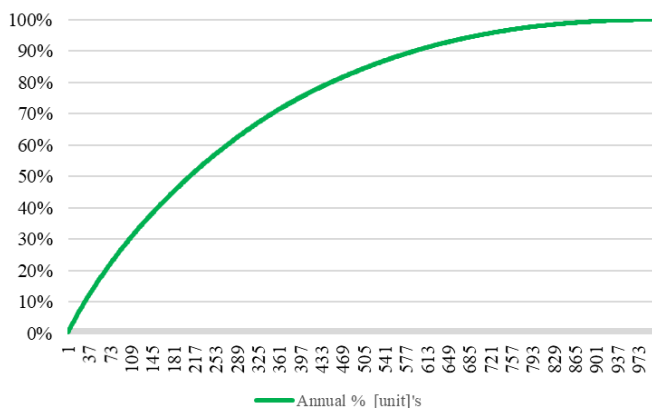


Figure 5: The ABC analysis curve

Then, we form the groups (A/B/C) along the annual value usage of total stocks. Figure 5. shows the inventory curve of usage on the company's products by the principles.

The rules of ABC classification:

- 80% annual cost of usage belongs to "A",

- 15% annual cost of usage belongs to "B",
- 5% annual cost of usage belongs to "C".

Table 3: Results of the ABC classification

Results	Item	% of items	% value of annual usage	Action
A	448	45%	80%	Close control
B	252	25%	15%	Regular
C	300	30%	5%	Infrequent
	1000	100%	100%	

Table 3. represents the results of the ABC classification: The group of "A" includes 448 items, where each product has high value usage of total stocks and use in large quantities over in given period. Close control is required to revise the following inventory management areas: assembly, warehouse, order, delivery, replacement and natural resources activities. Next group is "B", which has 252 items. The revise intensity is regular for the mentioned are as with less frequency of control. The last group is "C", which is required infrequent intervention. This group includes 300 items, there is low demand and higher risk of inventory costs.

After, we analyze the items according to usage fluctuations and forecast accuracy. Hence, we perform the XYZ analysis along the frequency of year.

Rules of XYZ classification:

- 200-365 day belongs to "X",
- 100-200 day belongs to "Y",
- 0-100 belongs to "Z".

Table 4. shows the results of the XYZ calculation.

Table 4: Results of the XYZ classification

Results	Item	% of items	% of annual value of frequency usage
X	453	45%	47%
Y	269	27%	26%
Z	278	28%	27%
	1000	100%	100%

Finally, we determine the ABC-XYZ classification based on the mentioned model approach (Table 5) to improve the inventory strategies for reducing costs.

Table 5: Results of the ABC classification

Results	A	B	C
X	211	116	126
Y	115	70	84
Z	122	66	90

Table 5. shows the exact product number on each class: The analyzed products are divided in nine different class-

es. The “AX” class has 211 products, 21%.; The Groups of “AY”/“AZ”/ “BX”/“CX” have different number of products: 116 - 126, ~12%-13%; The Groups of “BY”/“BZ”/ “CY”/“CZ” have different number of items: 66 - 90, ~7%-9%.

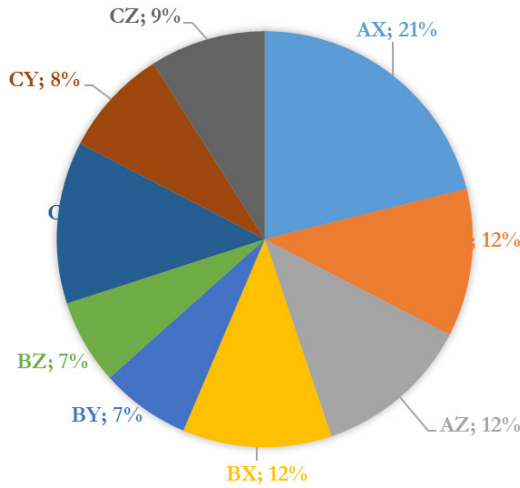


Figure 6: The ABC-XYZ classification classes [%]

Figure 6. demonstrates the results of the ABC-XYZ classification classes of percentage. The most costs of product are related to JIS supply strategy, where the material flow is high and permanent use. Also, we can identify that products which are needed more or less attention.

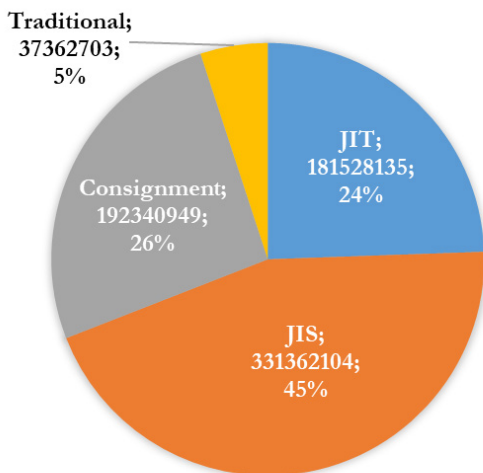


Figure 7: Purchasing cost on each inventory strategy [unit]; [%]

Based on the values of annual cost of usage in Figure 7., we can see that the largest percentage of our products (45%) are covered by just-in-sequence strategy.

As a summary for the above described ABC-XYZ analysis we can say, that based on the results of the combined ABC and XYZ analysis shown in Table 5 the optimal purchasing method can be chosen depending on the volume of products and the uncertainties of data. The assignment of purchasing strategies (JIS, JIT, Consignment, Traditional) depends on the size of each clusters in the ABC-XYZ matrix and the cost efficiency of purchasing strategies. For example in the case of AX product cluster the just-in-sequence supply is the optimal solu-

tions, while in the case of XC product cluster the conventional supply or the supply through a consignment store is the most suitable purchasing method.

CONCLUSIONS

The acceptance of inventory management in just-in-sequence solutions appears to be intensive in manufacturing technology. Just-in-sequence supply processes based on efficiency of the stocks lead to control the material flows within different scheduling and delivering needs, while the operation costs can be significantly reduced.

However, the optimal purchasing portfolio is led to increased usage of supply chain: (1) the minimalization of the level of stocks and materials, (2) increasing efficiency of inventory management activities, (3) solving decision making problems, (4) improving material flow intensity and (5) evaluating in aspects of natural and cost-based objective functions.

Inventory management is responsible for ensuring the required materials for manufacturing processes and services. The fictive company's sets of products were analyzed to determine that which products are economically significant.

The results can be able to improve decision making and evaluate the inventory strategies. The Just-in-sequence strategy support the supply processes to control their logistic processes and services.

The above mentioned analysis method is limited, because in the case of unknown or dynamic uncertainties, the product clusters are permanently changing, therefore it is not possible to choose the best purchasing method for a longer time window.

Nonetheless, there are also further directions in research. Formulation of other optimization models and solution methods can be extended with stochastic environment to solving multiple scheduling problems. The new approach will be able to analyze different time-frames and capacities of the just-in-sequence material flow and its operations.

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