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A SURVEY ON SUPERMARKET CONCEPT FOR JUST-IN-TIME PART SUPPLY OF MIXED MODEL ASSEMBLY LINES

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ABSTRACT: *Efficient and Flexible Just-In-Time part supply of mixed model assembly lines has become the main focus and challenge for industrial companies' especially automobile producers. In order to supply components to their mixed model assembly lines, more and more automobile producers are adopting the supermarket-concept.*

Within this concept, parts are intermediately stored in a supermarket, which is a decentralized logistics area near the assembly line, and then transported to workstations of assembly lines by means of tow trains. Tow trains visit the workstations of the assembly lines according to schedules and exchange empty with full part bins.

Existing literature on mixed model assembly lines deals either with balancing problem or sequencing problem. The part supply of mixed model assembly lines is a relatively new research topic and the literature explicitly dealing with decision problems related to in house logistics is scarce.

This paper presents the supermarket concept and surveys the research studies which tackle the decision problems related to the Just-In-Time part supply of mixed model assembly lines. Finally, it discusses benefits and limits of the supermarket concept.

KEYWORDS: *Mixed model assembly line, Part supply, Tow train, Just In Time, Supermarket, In-house logistics.*

1 INTRODUCTION

Recently, the main focus of the major part of companies in the automotive industry is shifted from the development of the final assembly line to its part supply process innovation.

An efficient JIT part supply plays a crucial role in enhancing productivity and flexibility.

Demands as well as diversified customers' requirements in automotive industry have increased. To be responsive to market change and flexible, many automotive manufacturers have implemented mixed model assembly lines. Mixed model assembly line occurs when more than one model of a general product are produced at the same assembly line. (Thomopoulos, 1967)

Mixed model assembly line has become important because of diversity. (Rekiek et al, 2000) and therefore the success of the company depends on its ability to manage the variety of products assembled in these lines by developing an efficient part supply system.

The importance of the development of the part supply and logistics processes is due the following trends:

-To ensure their competitiveness in the market, companies in the automotive industry must offer high quality products that meet all customer demands at low cost and in a short amount of time. To satisfy customer needs, compa-

nies offer them the possibility to customize their cars from a catalogue of options (e.g. colors, sunroof...). This generates a huge variety of parts to carry that become hard to manage. For instance, in the automotive industry,

production programs often comprise billions of different models (Boysen and Bock, 2011).

-Reliable and flexible part logistics process is essential to avoid in one hand, component shortages which leads to line stops and decreased productivity and in the other hand stocks near the line which not only increase inventory costs but also disrupts production because of the scarce storage space near assembly lines (Battini *et al.*, 2013).

-Many car manufacturers adapt a new sales strategy that showed its effectiveness in increasing the revenue per car. This strategy consists of allowing customers to update the chosen options for their cars until few days before the start of production (Battini *et al.*, 2013). This update may cause uncertainties for the planning process. Thus, a well planned and efficient supply chain organization become vital to companies.

For all those reasons, greater challenges are posed for cars manufacturer in efficient and flexible just in time (JIT) part supply for mixed model assembly lines.

That's why one of the major challenges in automobile production today is part supply process.

Following the Just in Time principals, automobile manufacturer adopt new strategies to ensure frequent small lot deliveries: The supermarket concept.

Within this concept, parts are intermediately stored in decentralized supermarket and then loaded on small trucking vehicles towing some wagons called tow trains. These tow trains make frequent small -lot- deliveries and travel on specific routes within the shop floor.

The main subject of this paper is the in-house logistics in automobile industry. This paper investigates the supermarket concept and surveys the research studies which tackle the decision problems related to the Just-In-Time part supply of mixed model assembly lines.

The remainder of this survey paper is organized as follows: section 2 describes in-house logistics, its different functions and supermarket concept for just in time part supply of mixed model assembly lines. Section 3 provides an overview of existing literature dealing with the supermarket concept and presents modeling and solution approaches used to solve decision problem related to JIT part supply of mixed model assembly lines working with supermarket concept system and discuss the benefits and limits of this concept. Finally conclusions are discussed in section 4.

2 IN-HOUSE LOGISTICS AND JIT SUPERMARKET CONCEPT

To be able to satisfy all customers' demands, companies in the automotive sector have to offer a wide range of different products (Faccio *et al.*, 2013). For example The German car producer BMW in Dingolfing supplies more than 13,000 containers delivered by more than 600 suppliers and 400 trucks (Battini *et al.*, 2013). The management of the flow of goods and information between suppliers and the point of consumption (stations at assembly lines) is called logistics.

In-house logistics is the part of the overall logistics process which focuses only on the management of material and information flow inside the company (where the parts have already received at the plant).

2.1 In-house logistics and its functions

The main fields of in-house logistics are: warehousing, transportation and production line organization (Battini *et al.*, 2013).

The first function of in-house logistics is the warehousing function. It focuses on part storage after receipt from external supplier. Traditionally, parts were stored at a central receiving store. Mostly, plants at the automotive sector are so large. Logistic operators suffer from distance between assembly lines and the central store which makes part supply less flexible. To remedy this problem, automobile plants adopt the so called "JIT-supermarket". Here, supermarket is a decentralized logistics areas

where parts required by the production lines are intermediately stored. Such a supply system enables a reliable small lot part supply in line with JIT-principles. (Emde and Boysen, 2012)

The second function of in-house logistics is the transport function. It focuses on transportation of raw material to a centralized warehouse or decentralized supermarket after being delivered from external suppliers, from warehouses to mixed model assembly lines or transportation of outstanding parts between assembly lines and finally transportation of finished product for shipping (Seidl and DVOŘÁK, 2012). To ensure the transportation function in in-house logistics three devices are used: forklift, tow train and feeder line.

Forklift is a relatively cheap transport device which is standardized (any type of material can be loaded in forklift) but it offers a very low capacity.

A tow train consists of a towing vehicle which is connected with few wagons which are loaded with parts. The train circulate through assigned stations and makes frequent small lot deliveries (Emde and Boysen, 2012).

Recently, tow trains became a popular way for a JIT-supply of mixed model assembly lines. Tow trains are used to deliver the required components to stations and to collect bins to be delivered for the next trip (Faccio *et al.*, 2013).

Tow trains are operated manually by human drivers or automatically as an automated guided vehicle (AGV) (Battini *et al.*, 2013).

Unlike a forklift, a tow train is less flexible but has much higher capacity, hence it optimizes delivery distance.

The last transport device is the feeder line which conveys parts directly to their respective stations. This device is so expensive and requires a very high investment.

The third function of in-house logistics is line presentation. The decision task here is to define the way a bin of parts is placed in assembly line. Assembly line is the place where the highest value addition takes place and which is very expensive in terms of production costs, worker density and materials investment. Hence, it's necessary to optimize the line side presentation to ensure an easy visual detection of parts, and an ergonomical aspect for assembly workers (easy access to parts). (Limère *et al.*, 2012), (Bozer and McGinnis, 1992).

Recently, many producers in the automotive sector focus on JIT part supply in order to make their logistics process more flexible, reliable and fast. This task becomes so hard when the assembly plant is composed of more than one mixed model assembly line.

2.2 The supermarket concept and its related decision tasks

The supermarket concept becomes more and more prevalent in the automobile industry. Many automobile producers have implemented and are currently implementing supermarket concept in order to ensure flexible and

reliable JIT part supply of their mixed model assembly lines.

A supermarket is a decentralized in-house logistics area where parts are intermediately stored then loaded on small tow trains which travel across the shop floor to make small-lot deliveries needed by the stations of the assembly line (see Figure 1). (Emde and Boysen, 2012)

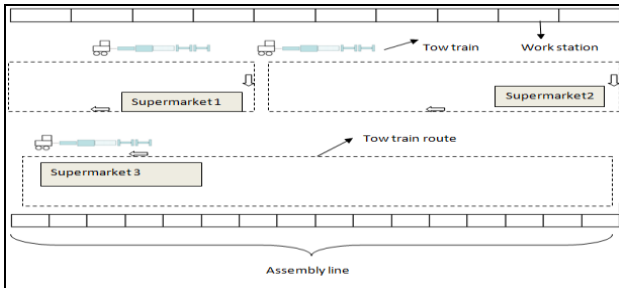


Figure 1: A layout of a shop floor working with the supermarket concept

The supermarket concept is relatively a new research topic. Several irrigated decision problems have to be solved in order to control the part supply process of mixed model assembly lines. These decision problems can be classified into four interrelated decision tasks. (Emde and Boysen, 2012)

- i) *Location planning problem* :Here the number of supermarkets to be installed on the shop floor, their locations and the assignment of line segments to supermarkets need to be determined.
- ii) *Routing problem*: This problem consists in determining the number of tow trains per supermarket (fleet size to be applied for part replenishment) and the route of each one. The route starts and ends in the supermarket and it consist of a sequence of stations to be visited by the tow train.
- iii) *The scheduling problem*: The decision task here is to determine each tow train's delivery schedule for supplying parts to stations on its route. Concretely, it is to determine for each train its number of tours, where a tour of a tow train consists of the complete cycle between its assigned stations and the loading operation in the supermarket, and the time for each stopover of each tow train (when to stop and supply each station assigned to the train).
- iv) *Loading problem*: The decision task here is to determine the number and types of part bins to be loaded per tour of each tow train. The loading problem aims to minimize inventory at stations while avoiding stock

outs. Tow train's capacity is limited and scarce.

The second (ii), third (iii), and fourth (iv) decisions investigate scheduling, routing, and loading problems which are the main focus of this study.

The following section will deal with an overview of literature dealing with JIT supermarket concept and will present the main decision problems to be solved.

3 LITERATURE REVIEW

According to (Emde and Boysen, 2012) the supermarket concept defined at the previous sections is a relatively new research topic and there is a little literature to date explicitly dealing with decision problems related to the supermarket concept. Some similarities can be found in previous studies, such as vehicle and inventory routing problems but none of them cover the delivery scheduling and tow train loading problems.

Unlike JIT supermarket concept problems, Customers in Vehicle Routing Problem (VRP) have to be visited exactly once (Dantzig and Ramser, 1959). The classical version of the VRP is single period and it excludes multiple deliveries which do not reflect the part supply operation of assembly lines.

In addition, VRP concerns only the routing aspect of the problem and does not take into account the scheduling aspect which is strongly related to the routing problem of tow trains (Emde and Boysen, 2012).

Several variations and specializations of the vehicle routing problem exist in particular multi-period versions (Cordeau *et al.*, 1997). The multi-period VRP (PVRP), consists in assigning customer visits to vehicle routes in some periods of a time horizon so as to satisfy frequency of visit required by customers, constraint on time lag between visits or predefined visit patterns (Angelelli and Speranza, 2002). So that, the scheduling is reduced to selecting a sequence of visits from a given set for each customer.

The Inventory routing problem (IRP) is concerned with repeated distribution of a product to customer over a given planning horizon (Campbell *et al.*, 1998). The IRP considers stochastic or constant consumption rate, delivery volumes assigned by the delivery company instead of the customer and capability of each customer to maintain local inventory of product which do not respect Just In Time concept which aim to minimize inventory .

Clearly, VRP and IRP models are not well adapted to organize part supply of mixed model assembly lines working with JIT supermarket concept.

The few recent studies dealing with JIT supermarket concept are presented bellow.

3.1 Literature dealing with the routing problem

(Vaidyanathan *et al.*, 1999) deal with the routing problem (ii) of tow trains. Their work is based on the well

known Vehicle Routing Problem which was modified and applied in the context of in-house logistics. They call the studied problem a Just In Time Capacitated Vehicle Routing Problem (JITCVRP). All workstations assigned to each tow train must be visited and served at each tour and the quantity to be delivered to each workstation depends only on the route assigned to the tow train and it must be just enough to supply workstation until the next arrival of the tow train. They presume a constant demand rate at each workstation which doesn't change over the time and tow trains travel across the shop floor on specific routes without breaks which means that the scheduling aspect is discarded. Thus their approach is confined to stationary environment. The immediate objective of JITCVRP is to minimize the total trip time of all available vehicles

A nearest neighbor algorithm is presented by (Vaidyanathan *et al.*, 1999) to generate start solutions for the routing problem (ii) for the just in time supply of assembly lines and subsequently the 3-opt heuristic to improve these solutions. They modeled the problem of planning routes for material delivery within a plant working with just in time production system by adding a non linear capacity constraint to classic vehicle routing model such that minimize the total travel time along the routes.

(Choi and Lee, 2002) study the routing problem (ii) of tow trains which are applied to supply a mixed model assembly line from a single warehouse.

In this study, the part feeding system is classified as static and dynamic system.

The hourly consumption rates of parts don't change over the time and are determined every day in the static part feeding system. In the dynamic one, the consumption amounts of parts are estimated dynamically considering the production progress.

In this paper, a dynamic feeding system is studied and the authors restricted their study of the routing problem to the design of routes of each tow train considering a predetermined fleet size.

A local search procedure is presented by (Choi and Lee, 2002) in order to solve the routing problem. The proposed solution method is tested in a real-world case in the automobile industry with the aim of minimizing the deviation of optimal delivery times per bin delivery.

The routing problem (ii) is studied by (Emde and Boysen, 2012). The routing problem is solved once for supermarkets and determines the subset of stations to be served by each tow train. To determine if the clustering of stations allows a feasible delivery system, the routing problem and scheduling problem are solved simultaneously.

(Emde and Boysen, 2012) present a nested dynamic programming approach to solve the routing (ii) of tow trains by finding fixed routes for each tow train.

The aims of the study are the minimization of the number of tow trains applied for replenishment.

(Golz *et al.*, 2012) present a case study from a German automobile industry and they study the routing problem (ii).

This study takes into consideration the supermarket concept. The authors aim at minimizing the number of tow trains applied for the replenishment of workstations of a mixed model assembly line.

The routing problem (ii) can be formulated as a mixed-integer linear program (MILP). The computational time burden when solving the problem by standard optimization software is prohibitive for real case. Hence, in order to solve the problem, (Golz *et al.*, 2012) develop a heuristic solution procedure which is based on the decomposition of the entire problem into two stages. First, identifying transportation orders from the given assembly sequence by part code, destination and due date. In the second stage, tours of the In-house shuttle system are generated such that the number of drivers (those involved in a part feeding process) is minimized as a consequence of minimizing the number of vehicles. So manpower costs which are considered as the main costs drivers in the part feeding system are saved as well as long term investment in transportation equipment are reduced.

(Faccio *et al.*, 2013) propose an optimization problem of a feeding system of an Italian automotive industry where multiple mixed model assembly lines are refilled means of a systematic part replenishment driven by Kanban system. Parts required by stations are initially stored in supermarkets than loaded on small tow trains and delivered to stations. In this paper, the authors study the routing problem (ii) to determine the number of tow trains to be applied for replenishment of the multiple mixed model assembly line and the kanban number. The author's presents in this paper a framework dealing with the long term strategic problem: Design and correlate the tow train fleet size and the kanban number. The authors propose a static model for long term strategic problem. Concerning the static model, the authors applied an analytical simple mathematical model to determine tow trains number and Kanban number. This first static step is based on averaged values of the considered parameters.

3.2 Literature dealing with the scheduling problem

In their paper, (Choi and Lee, 2002) study the scheduling problem (iii) of tow trains which are applied to supply a mixed model assembly line from a single warehouse.

The feeding system considered in this study is a dynamic one: Parts and workstations to be supplied are dynamically assigned to tow trains. The departure time of tow trains from the warehouse should be determined. The originality of this paper is the idea of designing routes and determining the departure time dynamically.

The scheduling problem (iii) is studied by (Emde and Boysen, 2012) simultaneously with the routing problem (ii) because they are heavily interdependent. While the

routing problem is solved once for supermarket and determines the subset of stations to be served by each tow train, the scheduling problem is solved for each tow train and determines the number of tours of each tow train and the start time of each tour. The decision variable of the routing problem serves as a parameter for the scheduling problem. Only solving the routing problem and the scheduling problem simultaneously can determine if the clustering of stations allow a feasible delivery schedule or not. (Emde and Boysen, 2012) present a nested dynamic programming approach to solve the scheduling problem (iii) of tow trains by finding cyclic as well as non cyclic schedules for tow trains. The aim of the study is the minimization of the stock level at the assembly line.

(Golz *et al.*, 2012) present also the scheduling problem (iii) in the case of a German automobile industry. This problem is addressed in (Choi and Lee, 2002) but it is not directly applicable in the case study presented in (Golz *et al.*, 2012) because they use different assumptions. For example, material shortages may occur in (Choi and Lee, 2002) and possible overflow of part inventories at stations is not considered which is not the case in (Golz *et al.*, 2012). The main object of this study is to avoid stock-outs. As well as the routing problem(ii) addressed in the same paper, the scheduling problem (ii) is formulated as a mixed-integer linear program (MILP). The authors develop an alternative approach for feeding parts to the assembly lines: First, transportation orders are identified in a predictive manner based on the production sequence, part code, destination and due date. In the second stage, tours of the In-house shuttle system generated when solving the routing problem are scheduled such as stock-outs at the line are avoided.

(Fathi *et al.*, 2014) study scheduling problem. In their paper, the authors treat the optimization of part feeding at mixed-model assembly lines motivated by a real problem encountered at one of the major automobile assembly plants in Spain through solving the decision problem based on the JIT-supermarket concept. The authors call the problem treated in their paper ALPFP (Assembly Line Part Feeding Problem) and the aims of the study are considered to be the minimization of the number of tours.

(Fathi *et al.*, 2014) present a mixed integer linear programming model (MILP) for the scheduling problem (iii) which is solved by CPLEX. The improvement criteria in this model are the number of tours. The authors present in this study a simulated annealing algorithm to solve the problem and give a comparison between the solution found by both the mathematical model and the proposed algorithm in terms of minimizing the number of tours.

3.3 Literature dealing with the loading problem

(Choi and Lee, 2002) consider in their paper the loading problem in the context of a dynamic part feeding system. A safety stock of each part should be respected at stations. Knowing the average length (in time) of a feeding cycle of each part and its consumption rate, the amount of parts required for next tour can be determined such that the expected level of stock of the part would not get down below the safety stock.

The loading problem studied by (Choi and Lee, 2002) is also studied by (Golz *et al.*, 2012). Transportation orders are determined in a first stage and in a second stage, transportation orders are assigned to tow trains taking transportation capacity restrictions and tours scheduling requirements into account. Parts in this case are supplied in bins of given size and only fully loaded bins are supplied at a station. A station may receive several bins holding the same or different part types. To solve this in-house logistic problem, a heuristic solution procedure is developed which has shown its effectiveness to solve even large-sized problem instances in short computational time.

(Emde *et al.*, 2012) tackle the loading problem (iv) of tow trains with limited capacities given routes and stations' demands to determine loading plan for successive tigger tours. The main objective here is to reduce simultaneously the sum and the maximum of inventories near the assembly line which obstructs assembly operations while avoiding material shortages. By assuming that routing is an input and cannot be changed, the maximum possible decrease in inventory is limited.

A polynomial time exact algorithm is developed by (Emde *et al.*, 2012) who tackle the loading problem of tow trains (iv) given their routes and schedules. They aim to minimize the number of bins stored at the line given a limited tigger capacity.

(Faccio *et al.*, 2013) propose in their paper an optimization framework of a feeding system of an Italian automotive industry. In their study, the authors study both routing problem(ii) and scheduling problem(iii) simultaneously. The loading problem (iv) is defined as a short term operational problem which aims to determine the best delivery frequency from supermarket to assembly lines and the vehicle capacity utilization. (Faccio *et al.*, 2013) present in their paper a simple and robust framework in order to design the feeding system of multiple and complex mixed model assembly lines. A static model is developed for the routing problem studied in this paper (see 3.1) and a dynamic model is developed for the short term operational problem. The result of the static model serves as inputs for the dynamic model which provide multi-scenario dynamic analysis to determine the best delivery frequency. The authors develop also a visual interactive simulation model using a discrete events tool to model the real system.

(Fathi *et al.*, 2014) present the loading problem (iv) at one of the major automobile assembly plants in Spain. The main objective of this study is to minimize inventory levels at workstations of the assembly lines. The performance measure called workload variation is considered also as criteria to improve. The workload is the amount of work a tow train driver has to do. In this paper, the authors aim to reduce the workload variation which means to reduce the overall variability among the work assigned to tow train drivers. It is obvious smaller workload variation value represent smoother workloads. The assessment of operator workload has a vital impact on the design of the part feeding system. Tow train driv-

ers should have the capability to carry the required transportation orders just in time.

3.4 Summary and conclusions

An overview of aforementioned studies is given in Table 1 in chronological order. In the first column the respective references are listed. Column two refers to the decision problem studied by the authors. Column three states the problem objective function used. In column four we some constraints are presented and finally in column five the proposed solution approach is given for each reference.

Reference	Problem			Objective(s)	Constraint (s)	Resolution method
	R	S	L			
(Vaidyanathan <i>et al.</i> ,1999)	X			min TTT	-The capacity of a vehicle delivery is limited. - All workstations assigned to each tow train must be visited and served at each tour -Quantity of parts delivered to each station must be just enough to supply workstation until the next arrival of the tow train	-Nearest neighbor algorithm and a 3-opt heuristic
(Choi and Lee,2002)	X	X	X		-The capacity of a vehicle delivery is limited.	-Local search procedure
(Emde <i>et al.</i> ,2012)			X	min SI min MI	-The capacity of a vehicle delivery is limited.	-Exact solution procedure
(Emde and Boysen ,2012)	X	X		min SI min NT	-Each tow train serves at least one station -Each tugger has sufficient time to finish a tour before the next one starts. -It is possible to satisfy customer demands in between any two tours without exceeding tow train capacity.	-Nested dynamic programming approach
(Golz <i>et al.</i> ,2012)	X	X	X	min NT	-One path is assigned to each tour and driver of a tow train.	-Heuristic
(Rao <i>et al.</i> ,2013)		X		min IHC min TC	-Only one destination workstation is served by the delivery vehicle. -No part is allowed to arrive at workstation after its due time. -The capacity of a vehicle delivery is limited.	-Mathematical model -GASA
(Faccio <i>et al.</i> ,2013)	X		X	min NT maxTTU	-The capacity of a vehicle delivery is limited.	-Optimization-simulation approach
(Fathi <i>et al.</i> ,2014)		X	X	Min SI MinNTo Min WV	-The capacity of a vehicle delivery is limited.	-MILP -Simulated annealing algorithm

R=Routing, S=Scheduling, L=Loading, TTT=Total Trip Time (of tow trains), SI=Sum of Inventories at the workstations, MI=Maximum Inventory at a workstation, NT=Number of Tow trains applied for replenishment, IHC=Inventory Holding cost, TC=Traveling Cost, TTU=Tow Train Utilization. NTo=Number of Tours, GASA=hybrid solution (Genetic Algorithm and Simulated annealing), WV=Workload Variation.

Table 2: Literature dealing with JIT supermarkets for part supply

The literature dealing with JIT supermarkets for part supply revealed that this concept showed its efficiency when it is applied to the automotive industries. So, it can be easily adapted to other industries which present a high variety production.

Additionally, the different models presented by the different existent papers can be well adapted to other real-world part supply problems by adding or removing some objectives and constraints.

We propose here new improvement criteria which should be considered in future studies.

Actually, supply chain managers are trying to keep costs low and reliability of their in-house logistic system up.

The real-world challenge of a logistic department of a high variety products industry where the part supply is managed by the consumption and therefore which exhibits a fluctuation grappled here is: how to reduce costs while ensuring smooth workload of the logistic team without hurting the efficiency of the part supply system ?

Papers analyzed in this studied have considered many criteria to optimize in order to reach the objective cited above such as: Number of tow trains applied for replenishment, tow train utilization, traveling and handling costs...

Some factors need also to be considered while optimizing the part supply system are:

- The minimization of the number of delayed deliveries. In fact, material shortages at workstations of an assembly line caused by a delay of an order delivery could cause line stoppage which gives raise to extra cost for the company.
- The maximization of the workload rate which represents the ratio of the trip time of a tow train and its takt time. This is important to minimize the considerable amount of unproductive time spent by logistics workers in traveling.
- The maximization of logistics efficiency which represents the ratio of the total handling and the sum of the total travel time and total handling time.

Finally the part supply system within the supermarket concept contains two tasks:

- The first task is performed by an operator called a shopping man or logistic worker. In the supermarket, the shopping man selects all parts required by the assembly stations, places them in a small bin (called kit) then kits are transferred to assembly stations.
- The second task is performed by the assembly worker who takes parts in the order from the kit and subsequently assembles them on the current workpieces (Jainury *et al.*, 2014).

This strategy has various benefits:

- It improves product quality: The fetching of parts required by the current workpiece during the production process become easy to assembly workers. Hence, the assembly worker becomes able to focus on assembling parts in a correct manner which leads to improve the product quality. (Samalley, 2009)
- Inventory at assembly stations are reduced. (Emde *et al.*, 2012).

This in-house supply process showed its efficiency in many automobile producers case. Nevertheless, this strategy shows its limits whenever a short term change of the production sequence or a defective part arises:

- Line stoppages can occur because of parts shortages caused by defective parts that are used in certain kits. So, kits that contain defective parts must be "reassembled." (Bozer and McGinnis, 1992)
- Double handling costs are increased because two types of workers are required here: Assembly workers and handling workers. This results in considerable logistics costs.

4 CONCLUSION

This paper deals with decision problems arising in the context of in-house logistics. It surveys literature dealing with Just In time supermarkets for part feeding of mixed model assembly lines in the automobile industry.

The survey of literature revealed that there are few studies in the area of just in time supply of assembly lines with the supermarket concept. However, this topic has only begun to be explored and since the year 2012 researchers have paid more and more attention to it.

The supermarket concept is an important logistics concept applied to in-house part supply in the automotive industry, which can be well adapted to other industries which are similar to the automotive one like production industries with high variety products.

The main purpose of implementing the supermarket concept is to ensure frequent small-lot delivery of parts which reduces inventories near the line and shortens resupply times. The decision of implementing the supermarket concept for part supply guides the supplier selection process: External suppliers who are able to provide material supply synchronized with in-house part deliveries are selected. So that, both procurement and in-house logistics processes are heavily interrelated.

Future research coupling procurement process and in-house part supply should be derived.

REFERENCES

- Angelelli, E., M.-G. Speranza, 2002. The periodic vehicle routing problem with intermediate facilities. *European Journal of Operational Research* 137, p. 233–247.

- Battini, D., N. Boysen., and S. Emde, 2013. Just-in-Time supermarkets for part supply in the automobile industry. *Journal of Management Control* 24, p. 209–217.
- Boysen, N., and S. Bock, 2011. Scheduling just-in-time part supply for mixed-model assembly lines. *European Journal of Operational Research* 211, p. 15–25.
- Bozer, Y.-A, and L.-F. McGinnis, 1992. Kitting versus line stocking: A conceptual framework and a descriptive model. *International Journal of Production Economics* 28, 1–19.
- Campbell, A., L. Clarke, A. Kleywegt, and M. Savelsbergh, 1998. The inventory routing problem, in: *Fleet Management and Logistics*. Springer, pp. 95–113.
- Choi, W.,and Y. Lee, 2002. A dynamic part-feeding system for an automotive assembly line. *Computers & industrial engineering* 43, p. 123–134.
- Cordeau, J.-F., M. Gendreau, and G. Laporte, 1997. A tabu search heuristic for periodic and multi-depot vehicle routing problems. *Networks* 30, p. 105–119.
- Dantzig, G.-B., and J.-H. Ramser, 1959. The truck dispatching problem. *Management science* 6, p. 80–91.
- Emde, S.,and N. Boysen, 2012. Optimally routing and scheduling tow trains for JIT-supply of mixed-model assembly lines. *European Journal of Operational Research* 217, p. 287–299.
- Emde, S., M. Flidner.,and N. Boysen, 2012. Optimally loading tow trains for just-in-time supply of mixed-model assembly lines. *IIE Transactions* 44, p. 121–135.
- Faccio, M., M. Gamberi, A. Persona, A. Regattieri, and F. Sgarbossa, 2013. Design and simulation of assembly line feeding systems in the automotive sector using supermarket, kanbans and tow trains: a general framework. *Journal of Management Control* 24, p. 187–208.
- Fathi, M., M.-J. Alvareza, V. Rodríguez, and F.-H. Mehrabanc, 2014. A multi-objective optimization algorithm to solve the part feeding problem in mixed-model assembly lines. *Mathematical Problems in Engineering*, in Press
- Golz, J., R. Gujjula, H.-O. Günther, S. Rinderer, and M. Ziegler, 2012. Part feeding at high-variant mixed-model assembly lines. *Flexible services and manufacturing journal* 24, p. 119–141.
- Jainury, S-M., R. Ramli, M-N-A. Rahman , and A. Omar, 2014. Integrated Set Parts Supply system in a mixed-model assembly line. *Computer and industrial engineering* 75, p. 266-273
- Limère, V., H.-V. Landeghem, M. Goetschalckx, E.-H. Aghezzaf, and L.F. McGinnis, 2012. Optimising part feeding in the automotive assembly industry: deciding between kitting and line stocking. *International Journal of Production Research* 50, p. 4046–4060.
- Rao, Y.-Q., M.-C. Wang, K.-P. Wang, and T.-M. Wu, 2013. Scheduling a single vehicle in the just-in-time part supply for a mixed-model assembly line. *Computers & Operations Research* 40, p. 2599–2610
- Rekiek, B., P. De lit and A. Delchambre, 2000. Designing mixed-product assembly lines. *IEEE transactions on Robotics and Automation* 16, p. 268-280.
- Seidl, M., and Z. DVOŘÁK, 2012. In-House Transport as a Part of Business Logistics. *Journal of Engineering Management and Competitiveness (JEMC)*, p. 1–5.
- Samalley, A, 2009. Toyota's new material-handling system shows TPS's flexibility. *Lean Management Institute*.
- Vaidyanathan, B.-S., J.-O. Matson, D.-M. Miller, and J.-E. Matson, 1999. A capacitated vehicle routing problem for just-in-time delivery. *IIE Transactions* 31, p. 1083–1092.
- Thomopoulos, N.-T, 1967. Line balancing sequencing for Mixed Model Assembly. *Management Science* 14, p. 59-75