Part-feeding Models and Techniques in an Automotive Environment: A Literature Review and Future Research Agenda

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Abstract: Part-feeding procedures are highly frequent in manufacturing processes and automotive environments. Part-feeding operations consist of picking operations occurring in the supermarket, and delivery operations that are studied as IRPs, TSPs, and VRPs. A great amount of resources is assigned to these operations and a high amount of equipment and components are handled in these processes. These practices are widely accepted and performed in manufacturing environments and are crucial for assembly or production operations. Indeed, picking operations might account for as much as 55% of the total warehouse costs. Because of this, many companies are striving to reduce costs and increase performances on these procedures. This paper provides a literature review of the Part-feeding practices that are related to the automotive environment. Furthermore, this paper identifies the key articles that investigate and research part-feeding procedures in relation to the automotive environments. Over the years, these practices have been adjusted, changed, or improved to increase their effectiveness. A clear and concise review of the papers on these subjects is needed to clarify the contribution that has been made and the necessary next steps to be done in the literature.

Keywords: Part-feeding, IRP, VRP, Picking, Automotive, In-house logistics.

1. Introduction and Background

The automotive sector employs a high number of people and accounts for a high percentage of the GDP. According to US Census Bureau (2018), the US exported approximately US-$ 13.901 bn and imported abound US-$ 30.91 bn worth of goods of automobiles and other transportation vehicles in January 2018. EU Publications described that the European automotive sector employs about 12 million people and accounts for around 4% of the GDP of the European Union. Within the automotive environment, the part-feeding operations are crucial for the assembly and production operations that are carried out in the plant.

Part-feeding operations ensured the delivery of references, which are stored at the supermarket, to the assembly line (Battini et al., 2010). There are four optimization methods that can be performed to improve the picking operations in a supermarket: batch-picking operations, routing order picking, and the storage assignment (Dukic and Oluic, 2007). During the picking operations, operators load a specific amount of references on tow trains. Tow trains (also called tugger trains), which are usually composed of an electrically powered engine and a handful of wagons, are used for the delivery operations. Vehicle Routing Problems (VRP), Traveling Salesman Problem (TSP), and Inventory Routing Problems (IRP) are used for planning the routes and the schedules of the delivery of references. Once the tow trains reach the assembly lines, references are delivered, and empty containers are loaded onto the tow trains. Since the space in the assembly area is limited, the quantity of references delivered is just enough to satisfy the demand of the station until the next arrival. There are three line-side presentations that are used to replenish the supermarket: load unit, traveling kit, and station kit (Battini et al., 2015). Load unit is the policy that consists of the delivery of containers filled with one lot of multiple identical parts. On the other hand, a traveling kit is a container composed of all the components needed to assemble a final product and travels with the product itself along the assembly line. Finally, the station kit is a container with all the components needed by a station for its assembly operations. Once a tow train has performed all the delivery operations in a plant, it reaches the supermarkets where it performs all the picking operations.

Over the years, these practices have been highly improved. With the increase in competition, automotive companies are strongly striving to improve part-feeding operations. A literature review is necessary to consider how the part-feeding practices have been developed. The aim of this paper is to provide a systematic literature review on the articles that concern the part-feeding problems within an automotive environment. Based on this research, the main trends are analyzed, and the future opportunities for research are presented.

2. Literature Review Methodology

The current literature was searched to identify the articles that better than other investigated part-feeding practices in an automotive environment. This research used Scopus since it is a database that has an abundance of material on this topic. Two main groups of keywords have been selected to perform this research.

- Group 1 contains keywords that are related to part-feeding problems ("*in house logistics*", "*in-house logistics*", "*part feeding*", "*part-feeding*", "*kitting*", "*inventory routing problem*", "*vehicle routing problem*", and "*picking*"),

- Group 2 envelops keywords that are related to the automotive sector ("*automotive*", "*automobile*", "*car manufacturing*", and "*car manufacturer*").

The articles that contain one keyword of both the two groups in the title, abstract, or keywords were selected. Further, only articles in English were taken into consideration, and the research was further reduced to four specific subject areas ("*Engineering*", "*Decision Science*", "*Computer Science*", and "*Business, Management and Accounting*"). At this stage, 123 hits were obtained, which were analyzed and considered for this review.

Further, these articles were analyzed, and their relevance was taken into consideration. A snowball search led to selecting 9 articles that were considered highly important for the part-feeding and logistic processes that took place in an automotive environment. The articles were then selected based on the title and abstract. A further selection step was to analyze more in-depth the articles available. This lead to finally identify 29 articles that were considered for this literature review.

This research aimed at finding the key articles that were relevant for the part-feeding procedures. Indeed, as it can be seen by the keywords that were chosen, this literature review wanted to include also VRP, TSP, and IRP since they were crucial for the part-feeding practices of an automotive environment. On the other hand, all articles that were related to the assembly line balancing problems, in-bound and out-bound practices, or other handling practices that might occur in manufacturing situation different from the automotive environment (Li et al. 2016) were discarded.

3. Literature Review analysis

The following figures describe the articles that were selected for this review. Figure 1 shows a summary of the journals that tackled the problem of part-feeding. As it can be seen, *International Journal of Production Economics*, *International Journal of Production Research*, *European Journal of Production Research*, *Journal of Manufacturing Technology Management*, *Journal of Management Control*, and *Industrial Management and Data Systems* are the journals that considered the most the part-feeding processes in an automotive environment.

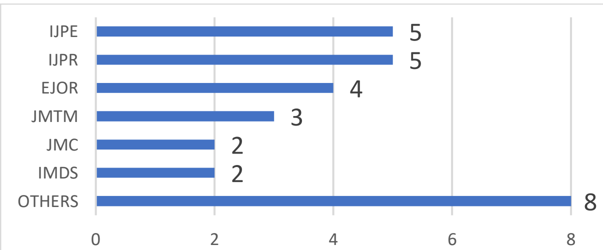

Figure 1: Number of articles on part-feeding per journal

Figure 2 shows what were the 15 most cited articles among the ones chosen for this review. For these articles, the numbers of citations in Scopus, in Google Scholar, and the Citation Score are provided. This Score was obtained by dividing a paper's number of citation found in Scopus by the number of years elapsed since its publication.

Figure 3 shows the authors that contributed the most in publishing papers about part-feeding procedures within an automotive environment. In this picture, the authors that published at least two articles on this topic are considered.

The structure of this literature review is based on the topics that were researched by the papers that were selected. These topics encompass the most important part-feeding activities that are performed in an automotive environment. By considering these topics, the most important aspects of the part-feeding procedures related to an automotive environment are considered. There are three main topics that were selected:

1)Reference Storage and Picking Methods: this group of papers describes approaches that have been developed to improve the storage of the references in a supermarket or the picking practices performed by the operators.

2)Delivery Models: this section encompasses all the papers that describe mathematical, linear programming, heuristic, and optimization approaches for the delivery of references from the supermarket to the assembly stations.

3)Line-side Presentation: this dimension describes how the references are delivered to the stations. According to Battini et al. (2015), there are three main line-side presentations that can be used: load unit, station kit, traveling kit.

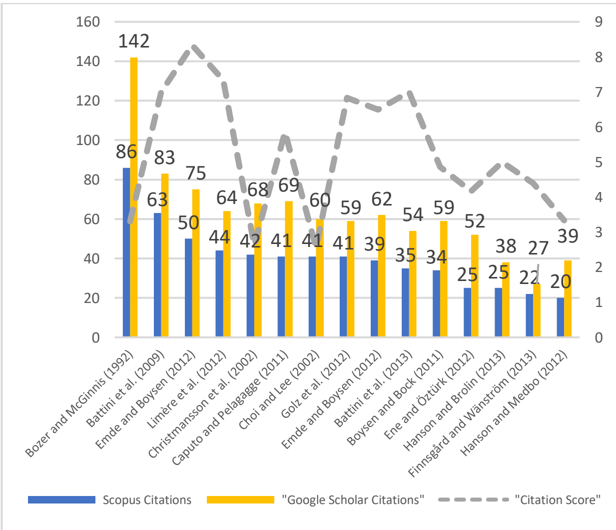

Figure 2: Most cited articles

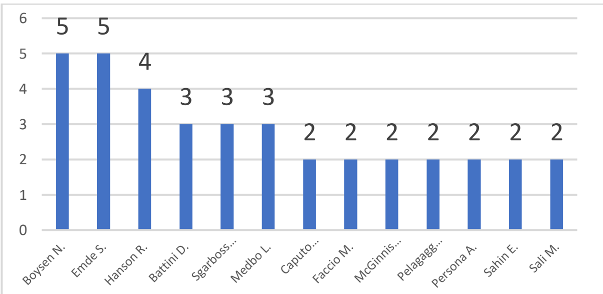

Figure 3: Most contributing authors (papers/author)

The 29 articles that are part of this literature review are classified into these three groups. If the topic of an article is related to two or more groups, it is at the discretion of the authors to decide which group to select based on the best possible description. Additionally, Table 1 shows the topics and the methodologies discussed in the papers.

Table 1: Main topics and methodology applied

		Case Study	Optimization Model	Heuristic Approach	Mathematical Model	Literature Review	Recursion Algorithm	Simulation Approach	Descriptive Model
Reference Storage & Picking Models	2012, Ene and Öztürk et al.		✓						
	2012a, Emde and Boysen et al.						✓		
	2013, Finnsgård and Wänström et al.	✓							
Delivery Models	2002, Choi and Lee et al.			✓					
	2011, Boysen and Bock		✓	✓					
	2012b, Emde and Boysen et al.						✓		
	2014, Fathi et al.		✓						
	2014,Boysen and Emde et al.			✓					
	2017, Emde and Gendreau et al.						✓		
	2017, Zhou and Peng et al.						✓		
Line-side Presentation Models	1992, Bozer and McGinnis et al.								✓
	2002, Christmansson et al.	✓							
	2009, Battini et al.								✓
	2011, Caputo and Pelagagge et al.	✓							✓
	2012, Bevilacqua et al.	✓							
	2012, Hanson and Medbo et al.	✓							
	2012, Hanson et al.	✓							
	2012, Limère et al.				✓				
	2013, Hanson and Brolin et al.	✓							
	2015, Caputo et al.		✓						
	2015, Sali et al.	✓							
	2016, Sali and Sahin et al.		✓						
Others	2006, Fredriksson et al.	✓							
	2011, Hanson et al.	✓							
	2012, Golz et al.			✓					
	2013, Battini et al.					✓			
	2013, Faccio et al.							✓	
	2015, Sternatz et al.		✓	✓					
	2016, Battini et al.		✓						

4.Literature Review discussion

The articles are divided among the three groups previously described.

4.1 Reference Storage and Picking Models

Ene and Öztürk (2012) improved the picking practices that were performed in a warehouse. Although this study was implemented in a regular manual warehouse rather than a supermarket, it presented some characteristics greatly important for the automotive industry. Firstly, the classes of the references, the distances of a 3D warehouse, and the picking orders were taken into consideration. A mathematical formulation was developed for the storage assignment. At a later step, an integer programming model addressed the order batching problem of the references and the routing problem of the picking vehicles. Furthermore, to decrease the computational time a Genetic Algorithm was encoded in order locations.

Emde and Boysen (2012a) defined the Supermarket Location Problem (SLP). This problem consisted of locating correctly the supermarket to supply an automotive assembly line. Indeed, the location of the supermarket might greatly affect the part-feeding operations since requires a high amount of resources continuously during the whole working shifts. They provided a polynomial-time dynamic programming algorithm to optimally solve the SLP. This algorithm was proved to be effective in real industrial cases, and other generalizations were provided about the implementation of the supermarket concept, and the optimal number of supermarkets to feed assembly line.

Finnsgard and Wänström (2013) analyzed the factors that might affect the picking operations in an automotive environment. The characteristics that where analyzed were part size, picking vertical offset, the angle of exposure of the container, sideways position, height available to pick, packaging, and the height of the exposed material container. These factors were analyzed to describe to what extent they affect the picking procedures. This study was performed through an experimental design to increase the generalization that could be obtained from it. This showed how these factors could impact the picking time since the measured variable was the time spent in picking operations by the operators.

4.2 Delivery Models

Choi and Lee (2002) provided a formulation for determining the quantity consumed by the stations. Unlike other models that considered statically the quantity consumed by the station (i.e. it does not vary for a production cycle), this model determined dynamically the quantity consumed by an automotive assembly line (i.e. the quantity demands from the production cycle). To solve this problem, a dynamic model was provided that obtained results that were close to the actual quantity consumed by the stations. This model was used to calculate the data of the consumption of the stations which is then provided to the delivery vehicles. They showed how this model could be implemented to improve the accuracy of the forecast of the station's demands.

Although the use of forklifts in part-feeding operations is unconventional in the automotive sector, forklifts might be implemented due to real life situations or specific layout features. Boysen and Bock (2011) analyzed the scheduling problem of the delivery of references with forklifts in the pallet to work station-policy. In this case, the diversity of the automobile models produced was greatly affected by the part-feeding operations. The authors provided a dynamic programming to solve this problem. This approach was tested and compared with a simulation. A study was performed on the interface between the sequencing problem in an assembly line and the in-house part-feeding models. This study considered the effects of leveled production sequences in the inventory level.

Emde and Boysen (2012b) continued the worked previously discussed in Emde and Boysen (2012a) by addressing the replenishment problems that might arise in an assembly line of an automotive environment. Taken the quantity that must be supplied to the stations as an input, they provided a formulation to solve the combination of the Vehicle Routing Problem (VRP) (i.e. routing correctly the delivery of references) and the Supermarket Scheduling Problem (SSP) (i.e. scheduling the delivery of the references). Although this formulation neglected any consideration on the consumption rates of the stations, it determined all the information needed for the delivery of references. A nested dynamic programming procedure was provided to obtain exact solutions.

Fathi et al. (2014) described a new model for the optimization of the part-feeding problem at a mixed-model assembly line. The authors provided a mixed-integer programming and a heuristic approach that is based on a simulated-annealing algorithm. The aim of this approach was to minimize the number of tours and the inventory level at the stations. This approach was able to provide good solutions with short computational times.

Boysen and Emde (2014) defined the line-integrated supermarkets. This new concept consisted in introducing supermarkets of limited dimension in the proximity to the assembly stations, and to assign operators to perform picking operations there. This approach was showed to be more effective than line stocking and kitting for safety problems, ergonomic issues, and unproductive time that might occur at a station. The authors described the problem, analyzed the complexity, and provided a heuristic approach to schedule correctly the feeding operations and to minimize the number of operators tasked with these practices. Eventually, some qualitative results based on the analysis were provided.

Emde and Gendreau (2017) defined the Tow Trains Scheduling and Loading Problem (TTSL). This problem consisted of combining the schedule of the delivery of references and the loading and unloading procedures. As described by the authors, the unloading and loading time, which affected the delivery of references, may vary dramatically based on the kind of tow trains and the size of the vehicles and containers. The time complexity of the problem was assessed. The authors provided a recursion algorithm to obtain the optimal load of the tow trains. Furthermore, a MIP formulation was provided to optimally solve the problem, and a heuristic approach was given to obtain a solution with short computational times.

Zhou and Peng (2017) studied the inhouse delivery problem to Mixed-model Assembly Lines. The delivery was performed from a decentralized logistics area with vehicles of limited capacity. The model was a point-to-point JIT which defined the destinations and the quantity that must be delivered with the aim to minimize the maximum weighted inventory across all the stations. Similarly to other VRP and IRP models, a mathematical model was provided. An exact backtracking procedure was presented to optimally solve small-scale problems. To solve large real-life problems, a modified metaheuristic approach developed first solutions that were then improved with differential evolution loop and breadth-first search.

4.3 Line-side Presentation Models

Bozer and McGinnis (1992) provided a structure to conduct research on line-side presentation. Qualitative evaluations of the kitting line side presentation were described. The authors admitted that some of the assumptions made were simplistic. The results showed that the shop floor space and the time for picking operations decreased due to kitting presentation.

Christmansson et al. (2002) investigated the physical workload and the time needed for picking operations under two different circumstances: plastic containers, or Euro pallet. The authors highlighted how the picking time could be decreased with some technical improvements. The most important finding was that a reduction in the time losses, which lead to higher productivity, was not necessarily related to higher workload or harder ergonomic situations for the operator. The work also suggested the use of integrated diagrams to better understand how different parameters affect the ergonomic workload and the time consumption.

Battini et al. (2009) described a new approach to select the appropriate feeding policy. This model considered the centralization and decentralization of the costs to minimize the stocking costs. This aspect was combined with the material handling policy to obtain the optimal solution in terms of costs. Using this model, the best degree of decentralization for the stock of the references could be obtained based on some parameters. Furthermore, this model could combine this decision with the selection of the part-feeding policy.

Bevilacqua et al. (2012) described a model for the kitting system. This work consisted of implementing a new kitting system in a luxury car maker. This new improvement allowed to obtain higher area savage, a cleaner production area, and lower work in progress in an assembly environment. Furthermore, the economic savings obtained were analyzed. Furthermore, some errors that were performed in this implementation project were presented to avoid them in future situations.

Hanson and Medbo (2012) discussed the line-side presentation as a combination of kitting and continuous supply. The authors described that the optimal feeding method was a combination of these two delivery models and provided a model to select which method to implement. The benefits and the drawbacks of this decision in terms of time needed for the operations were discussed.

Caputo and Pelagagge (2011) described an approach to select the most appropriate line-side presentation. They provided descriptive models, empirical criteria, and a case study. These tools could be used to define the most appropriate line-side presentation. Furthermore, the model analyzed also the performance of the current practice.

To continue this work, Hanson et al. (2012) analyzed the effects of kitting and continuous supply. This research was made from the quantitative point of view rather than the qualitative approach. To perform this study, two major situations were considered: the supply is performed close or far from the assembly line, the operators need to perform or could avoid searching operations to pick items from a kit. The kitting and the continuous supply were compared under these two situations. Further aspects were considered in comparing these two line-side presentation models. The time needed for assembly operations, for picking operations, and for transporting operations was considered.

Limére et al. (2012) developed a mathematical model to select whether to apply kitting or line stocking practices in the line-side presentation. Unlike other previous works, this model assigned to every single component an appropriate line-side presentation method. This approach considered some space constraints that were related to the limited space in the production line. This selection was based on a cost-effective model for the material supply.

Hanson and Brolin (2013) discussed traveling kitting, stationary kitting, and continuous supply. This work presented the effects of this choice on four performance areas: time consumed, quality, flexibility, and the space requirements and inventory level. Two case studies analyzed the effects on the assembly plant and on in-house material supply. Furthermore, this paper described how the effects arose. This allowed understanding how to exploit the full potential of these part-feeding techniques. The results given could be used to successfully select the line presentation that best fitted to a plant's productive environment. On the other hand, this work provided a clearer understanding of how to avoid side effects.

Sali et al. (2015) discussed the difference in line stocking, traveling kit, sequencing. This paper discussed the performance in term of costs of these three part-feeding approaches and presented the conditions for the less expensive model. The associated costs, which included costs of preparation, transportation, picking and storing operations, of the three approaches were discussed. Eventually, an empirical analysis on a large number of scenarios and situations (i.e. components' features, packaging, and settings) was performed. This analysis identified the best conditions to implement one of these three line-side presentations. This yielded a ranking of the line-side presentations. This model could be adjusted and extended to adapt it better to a plant's characteristics.

Caputo et al. (2015) continued the previous work. They described an optimization approach to select the best line-side presentation method. In this case, there were three line-side presentations that were taken into consideration: kitting and continuous supply, which was divided in line-stocking and just-in-time supply. The authors provided a linear programming mathematical model to minimize the total costs which included the workers costs, investment costs, holding costs and floor space utilization. A case study and a sensitivity analysis were described.

Sali and Sahin (2016) considered three line-side presentations: stationary kitting, sequencing kitting, and line stocking. A mathematical model was provided which was used to support the decision of selecting the most efficient line-feeding method. The total costs (picking, transportation, preparation, and storage) were considered to select one model over the other. This model identified all the different components of the costs. Finally, a parametric analysis was performed to show how the parameters could affect optimization.

4.4 Others

Frediksson (2005) discussed some logistics and operations problems that might arise in modular assembly processes. These issues were identified under case studies that were based on Toyota, Saab, and Volvo's production plants. This work found the critical problems and those aspects that are important for the assembly process. The authors divided the problems that were found from the context and discussed the solutions that were implemented such as the interaction between organizational units and with the suppliers. The work described also the issues that could be found in a modular environment so that they are clear for firms that want to implement this model.

Minomi is a group of components that are picked up, transported, and delivered without any container. Furthermore, they could be moved as a single mass. Hanson (2011) discussed the use of this line-side presentation by providing its effects. He explained how in certain cases minomi could reduce the time needed for the supply operations and assembly operations. Furthermore, the space that is occupied by materials on racks could be reduced if a minomi approach is implemented. Eventually, the side effects of the minomi model are presented. This work described how a production model will be influenced by the minomi concept as a useful tool to decide whether to implement this approach.

Golz et al. (2012) modelled the part-feeding problem in the high-variant mixed-model assembly line. The authors discussed how in these situations the problem was the high variability of the parts and of the quantity. For such problems, they provided a heuristic solution, which aimed at smoothing the workload at the line with the use of mixed-model sequencing approaches. This method divided the problem into two stages: firstly, delivery locations, references delivered, and time limits were identified, then the delivery tours and scheduled were planned. This model minimized the peak demand for the drivers.

Faccio et al. (2013) investigated the inventory stock level and fleet size trade-off problem which is complex for multi mixed-model assembly lines, and they provided a structure to develop a feeding system for such lines. This structure consisted of two steps: a first long-term fleet-Kanban number sizing problem, and a second dynamic system for short-term loading policy. The latter is based on a simulation for the short-term fleet management problem, and the former is a static model. This approach considered factors related to the quantity of references to deliver, the service level, and the vehicles used.

Battini et al. (2013) provided a literature review of the supermarket concept. In this literature review, a qualitative model was provided to select the most appropriate options available for the supermarket concept. Three dimensions were taken into consideration: warehousing methods, line-side presentation, and transportation modes. For each of these dimensions, some options were provided and described. This provided a better understanding of the implementation policy and process.

Sternatz (2015) presented a work to improve the assembly balancing line problem and the material supply problem. The aim of this work was to simultaneously optimize the workload among the stations and the problem related to the delivery of references to the stations. The first model provided was an optimization model. Then a heuristic approach was described, as well as, some guidelines for improving these practices were provided.

Similar to the work of Sternatz (2015), Battini et al. (2016) described an approach for solving the integrated assembly balancing problem and the part-feeding problem, which they defined as the Integrated Assembly Line Balancing and part Feeding Problem (IALBFP). They provided a mixed-integer programming model to solve this problem. Differently from the work of Sternatz (2015), some considerations were made on the ergonomic workload. The part-feeding procedures were performed under lean considerations and synchronized with the assembly operations.

5. Future Research Agenda and Conclusion

In this literature review, 29 relevant works that describe and solve the part feeding problem in an automotive environment were presented. The papers were divided into three main groups: reference storage and picking models, delivery models, and line-side presentation. This review explains the areas that have been broadly studied, and the areas that have been neglected. Although some insights on the state of the art of the literature have been provided, many research fields that are somehow related to the logistic in-house operations have been neglected. However, the aim of this paper is to discuss only part-feeding problems that are related to the automotive sector.

Furthermore, this research would like to provide some insights for possible future research. These suggestions have been organized into the three main topics upon which the papers have been divided:

1) *Reference Storage and Picking Models*: Although there are works that addressed the problem of storage assignment and the order-batching, there is a lack of approaches that consider zone picking – i.e. picking operators that pick references in a single zone – as a viable method for improving the picking process.
   As well, ergonomic issues linked to the physical workload of the human operators involved in picking tasks inside the supermarket have not be taken into consideration in the literature. Future research in this field should consider the human element impact on warehousing and picking operations as well also the possibility to introduce new assistive equipment, collaborative technologies, digital solutions to help the pickers during their manual work (for example, the use of Robotic Mobile Fulfilment Systems in order picking applications could be also investigated).
2) *Delivery Models*: IRPs, TSP, and VRPs have been largely discussed for their implementation in an automotive environment. On the other hand, congestion problems might hinder greatly the delivery of references, thus, leading to lower utilization rates, inefficiencies, and stockout situations. Thus, there is a lack of research on the influence of congestion on the delivery of references in an automotive environment. Furthermore, the importance of the network of the roads related to IRPs, TSPs, and VRPs has never been fully assessed. The design of the network might somehow affect the execution of the delivery models that are used to plan the part-feeding process. Indeed, improvements in the network have never been considered relevant for the delivery of references. Not much can be found about how to select the delivery method and policy (whether using IRP, TSP, or VRP models) based on the line-side presentation. This problem has been neglected under both the quantitative and the qualitative point-of-view. There might be some considerations that lead a delivery model to be best fit for one of the line-side presentation methods adopted.
3) *Line-Side Presentation*: There are some models that describe which line presentation select and how implement it a part-feeding process. On the other hand, there is no model or heuristic approach that deals with the choice of the best line-side presentation policy for a specific assembly part, according to the part parameters as size, volume, consumption, value, etc. The current literature describe this problem by different point of views, without offering a complete decision support model to define the best feeding policy for each part.

Finally, the current literature does not solve the picking optimization, line-side presentation, and delivery model together as a whole under either a qualitative or semi-quantitative point of view. These are three components of the same operations that can affect one another. The literature does not provide a combined model to solve these problems simultaneously.

6. Reference

Battini, D., Boysen, N. and Emde, S., 2013. Just-in-Time supermarkets for part supply in the automobile industry. *Journal of Management Control*, *24*(2), pp.209-217.

Battini, D., Calzavara, M., Otto, A. and Sgarbossa, F., 2016. The integrated assembly line balancing and parts feeding problem with ergonomics considerations. *IFAC-PapersOnLine*, *49*(12), pp.191-196.

Battini, D., Faccio, M., Persona, A. and Sgarbossa, F., 2009. Design of the optimal feeding policy in an assembly system. *International Journal of Production Economics*, *121*(1), pp.233-254.

Battini, D., Faccio, M., Persona, A. and Sgarbossa, F., 2010. "Supermarket warehouses": stocking policies optimization in an assembly-to-order environment. *The International Journal of Advanced Manufacturing Technology*, *50*(5-8), pp.775-788.

Battini, D., Gamberi, M., Persona, A. and Sgarbossa, F., 2015. Part-feeding with supermarket in assembly systems: transportation mode selection model and multi-scenario analysis. *Assembly Automation*, *35*(1), pp.149-159.

Bevilacqua, M., Ciarapica, F.E. and Paciarotti, C., 2012. Supply chain integration in an Italian automotive company: the case of a kitting system implementation. *International Journal of Productivity and Quality Management*, *10*(4), pp.428-446.

Boysen, N. and Bock, S., 2011. Scheduling just-in-time part supply for mixed-model assembly lines. *European Journal of Operational Research*, *211*(1), pp.15-25.

Boysen, N. and Emde, S., 2014. Scheduling the part supply of mixed-model assembly lines in line-integrated supermarkets. *European Journal of Operational Research*, *239*(3), pp.820-829.

Bozer, Y.A. and McGinnis, L.F., 1992. Kitting versus line stocking: a conceptual framework and a descriptive model. *International Journal of Production Economics*, *28*(1), pp.1-19.

Caputo, A.C. and Pelagagge, P.M., 2011. A methodology for selecting assembly systems feeding policy. *Industrial Management & Data Systems*, *111*(1), pp.84-112.

Caputo, A.C., Pelagagge, P.M. and Salini, P., 2015. A decision model for selecting parts feeding policies in assembly lines. *Industrial Management & Data Systems*, *115*(6), pp.974-1003.

Choi, W. and Lee, Y., 2002. A dynamic part-feeding system for an automotive assembly line. *Computers & industrial engineering*, *43*(1-2), pp.123-134.

Christmansson, M., Medbo, L., Hansson, G.Å., Ohlsson, K., Byström, J.U., Möller, T. and Forsman, M., 2002. A case study of a principally new way of materials kitting—an evaluation of time consumption and physical workload. *International Journal of Industrial Ergonomics*, *30*(1), pp.49-65.

Dukic, G. and Oluic, C., 2007. Order-picking methods: improving order-picking efficiency. *International Journal of Logistics Systems and Management*, *3*(4), pp.451-460.

Emde, S. and Boysen, N., 2012b. Optimally routing and scheduling tow trains for JIT-supply of mixed-model assembly lines. *European Journal of Operational Research*, *217*(2), pp.287-299.

Emde, S. and Boysen, N., 2012a. Optimally locating in-house logistics areas to facilitate JIT-supply of mixed-model assembly lines. *International Journal of Production Economics*, *135*(1), pp.393-402.

Emde, S. and Gendreau, M., 2017. Scheduling in-house transport vehicles to feed parts to automotive assembly lines. *European Journal of Operational Research*, *260*(1), pp.255-267.

Ene, S. and Öztürk, N., 2012. Storage location assignment and order picking optimization in the automotive industry. *The international journal of advanced manufacturing technology*, *60*(5-8), pp.787-797.

EU Publications. Directorate-General for Internal Market, Industry, Entrepreneurship, and SMEs. GEAR 20130 Strategy 2015-2017 – Comparative analysis of the competitive position of the EU automotive industry and the impact of the introduction of autonomous vehicles.

Faccio, M., Gamberi, M., Persona, A., Regattieri, A. and Sgarbossa, F., 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*(2), pp.187-208.

Fathi, M., Alvarez, M.J., Hassani Mehraban, F. and Rodríguez, V., 2014. A multiobjective optimization algorithm to solve the part feeding problem in mixed-model assembly lines. *Mathematical Problems in Engineering*, *2014*.

Finnsgård, C. and Wänström, C., 2013. Factors impacting manual picking on assembly lines: an experiment in the automotive industry. *International Journal of Production Research*, *51*(6), pp.1789-1798.

Fredriksson, P., 2006. Operations and logistics issues in modular assembly processes: cases from the automotive sector. *Journal of Manufacturing Technology Management*, *17*(2), pp.168-186.

Golz, J., Gujjula, R., Günther, H.O., Rinderer, S. and Ziegler, M., 2012. Part feeding at high-variant mixed-model assembly lines. *Flexible Services and Manufacturing Journal*, *24*(2), pp.119-141.

Hanson, R., 2011. Effects of using minomi in in-plant materials supply. *Journal of Manufacturing Technology Management*, *22*(1), pp.90-106.

Hanson, R. and Brolin, A., 2013. A comparison of kitting and continuous supply in in-plant materials supply. *International Journal of Production Research*, *51*(4), pp.979-992.

Hanson, R. and Medbo, L., 2012. Kitting and time efficiency in manual assembly. *International Journal of Production Research*, *50*(4), pp.1115-1125.

Hanson, R., Medbo, L. and Medbo, P., 2012. Assembly station design: a quantitative comparison of the effects of kitting and continuous supply. *Journal of Manufacturing Technology Management*, *23*(3), pp.315-327.

Limère, V., Landeghem, H.V., Goetschalckx, M., Aghezzaf, E.H. and McGinnis, L.F., 2012. Optimising part feeding in the automotive assembly industry: deciding between kitting and line stocking. *International Journal of Production Research*, *50*(15), pp.4046-4060.

Sali, M. and Sahin, E., 2016. Line feeding optimization for Just in Time assembly lines: An application to the automotive industry. *International Journal of Production Economics*, *174*, pp.54-67.

Sali, M., Sahin, E. and Patchong, A., 2015. An empirical assessment of the performances of three line feeding modes used in the automotive sector: line stocking vs. kitting vs. sequencing. *International Journal of Production Research*, *53*(5), pp.1439-1459.

Sternatz, J., 2015. The joint line balancing and material supply problem. *International Journal of Production Economics*, *159*, pp.304-318.

U.S. Census Bureau, 2018. U.S. International Trade in Goods and Services, January 2018, Release Number: Release Number: CB 18-33, BEA 18-11.

Zhou, B. and Peng, T., 2017. Scheduling the in-house logistics distribution for automotive assembly lines with just-in-time principles. *Assembly Automation*, *37*(1), pp.51-63.