Conceptual approach for adaptive production line feeding system

Tamás Bódis[1], Adrián Horváth[1] and Péter Földesi[1]

[1] *Logistics and Forwarding Department, Széchenyi István University, Hungary*

Abstract. The production line feeding operations are responsible for handling raw materials, parts and semi-finished goods from buffers and warehouses to the right assembly position of the production line. Further responsibilities are the material handling of the semi-finished and finished goods from the production line to the buffers or warehouses. The complexity of logistics operations has already been increased because of the fragmented orders, the shrinking time windows the shortening product lifecycle, the huge product portfolio, the different special customer requirements for the same product (e.g. Packaging, labelling, sequencing) and inventory reduction purposes. Besides the complex systems, the environment and the customer requirements are changing continuously. The proposed paper highlights the necessity of adaptive line feeding algorithms and describes a promising concept to keep up the effectiveness of the systems in the case of changing circumstances with adaptive process definition, location-vehicle allocation, and scheduling.

1 Introduction

The production line feeding (LF) related material handlings should be scheduled within time windows to ensure the part stock on the assembly positions and avoid the fully loaded (semi-)finished good buffers. The buffers and stock make us able to schedule within time windows. The higher amount of stock at the assembly position and the higher buffer capacities increase the time windows and decrease the number of material handling, but these require valuable space form the production area. The nowadays trending decreased time windows and increased number of material handling result in growing LF complexity and optimization requirements. [1]

Several researches have been done on the field of LF problem to define the right processes and parameters for the given cases. Baller, et al. made a detailed state of the are research about the LF policies and extended the existing mixed-integer programming formulations of the literature by modeling nine different LF policies. [1] Emde and Gendreau highlighted the challenges of LF optimization, proved strong NP-completeness of the problem, and presented exact and heuristic solution methods. They highlighted the commonly used simple cyclic schedules are clearly outperforming. The authors provided some managerial insight for the right degree of automation for LF systems. [2] Caputo, et al. examined the impact of part features (i.e. unit size, cost) on the LF costs, considering the right LF policy for the part types. [3] Sali, et al. proposed an optimization model to define the most efficient LF method from the line stocking, kitting, and sequencing for each component. The authors developed and applied a mixed integer program to a first-tier automotive supplier. [4]

Based on our state-of-the-art research we need to highlight, although the usually changing logistics requirements increase the necessity of the adaptive logistics systems, still there is a lack of algorithms considering adaptive features for the complex LF systems. Since the proportion of produced different product usually change and the different characteristics production plan usually requires diverse amount of parts, the strict location-vehicle allocation, processes and scheduling methods can not keep up the effectiveness of the logistics system all time. An adaptive LF system would be able to actualize the allocation, define the fitting process and keep the balance of the operators with scheduling on demand.

2 Adaptive line feeding approach

The aim of the proposed adaptive LF concept is to support the operations to be able to adjust to the actual circumstances automatically without implementing new algorithms or system setups and keep up the efficiency of the operations.

In the case of LF the proposed model has three main strongly connected fields for optimization and harmonization:

- Material handling policy definition
- Location Assignment Problem (LAP)
- Task Assignment and Scheduling Problem (TAS)

2.1 Material handling policy definition

During the material handling policy definition, it is necessary to define the possibly applicable processes and the decision points in the frame of a preliminary tactical or strategical project.

The main design procedure is general, like defining the departure methodology, the transport possibilities between locations and the route types. The departure methodology for the warehouses or depos can be continuous when a vehicle is ready to start then move the already prepared units. In the case of the demand driven departure, the ordered units of the locations are prepared and when the vehicle and the units are ready then the transport will depart. The route-plan based departure ensures a preliminary defined starting time when the vehicle and the units should be ready to depart. Besides defining the right material handling policies based on the state of the art research [1], the possibilities of transports between location with eliminating the warehouses and depos should be discussed. The task definition, scheduling and allocation should be defined. The possibility of the direct and cycle route types and the route planning procedures also should be defined.

The mentioned decision filed should be discussed for the given use case and define the primary and the possibly applicable procedures and those required circumstances. It results in, the system will be able to adapt automatically different methodology when the environment is changed. To let the system able to make the right decision it is important to model the given use case, simulate and evaluate several scenarios and define a machine learning algorithm for the real time decision making.

2.2 Location Assignment Problem (LAP)

The Location Assignment Problem (LAP) is responsible for allocating at least one vehicle from the vehicle pool for every location in the frame of a preliminary tactical design project. Locations are assembly positions or (semi-)finished good buffers in the case of LF. When only 1 vehicle is allocated to the location, then it is a strict definition when the given location will be managed by the defined 1 vehicle. When more the 1 vehicle is defined for the location in a flexible allocation, then the Task Assignment and Scheduling Problem (TAS) algorithm will decide which vehicle will manage the material handling in the given case based on priorities route by route. Since Emde and Gendreau highlighted the commonly used simple cyclic schedules are clearly outperforming, the LAP and the TAS together supports to keep up the effectiveness. [2]

The LAP should define and evaluate possible combinations of vehicles and locations. The combination definition should consider the number and properties of the vehicles, the task characteristics and properties of the locations, and the route network with the locations. One of the most important research questions of the LAP during the combination generation is defining when it is necessary to manage strict and flexible allocations. Furthermore, the LAP supports the TAS with decreased set of possible cases for the shorter scheduling runtime and keeps the material handling tasks more logical for the human operators.

The possible allocation combinations should be evaluated based on the material handling and transport policies and the TAS algorithm to define a harmonized operation. For this optimization and evaluation, the same simulation model can be possible which was defined for material handling policy definition.

The LAP results in one allocation which will be used by the Task Assignment and Scheduling Problem (TAS) in operation until reengineering by LAP.

2.3 Task Assignment and Scheduling Problem (TAS)

The Task Assignment and Scheduling (TAS) algorithm is responsible for assigning and scheduling the exact material handling tasks for the vehicles on the operational level based on preliminary defined material handling processes, the location-vehicle assignments and the actually opened tasks.

The algorithm should assign the tasks for one of the allocated vehicles by the LAP based on priorities. When the given circumstances require the TAS should realize the changed environment and should offer to change the material handling and transport procedure from the primary to the adequate procedure. Probably any big data and artificial intelligence method will make the TAS be able to do the right offer.

The TAS should result in scheduled routes for vehicles route by route with the ordered contents, starting time, operation policy and estimated finishing time.

2.4 Industrial example

There is a factory where 3 production lines (A, B, C) are supplied with parts from the same warehouse. In general cases every line is producing with 90% utilization. Every vehicle supply positions of one line as priority but has opportunity to work for other lines in the case of changing circumstances.

When the ordered quantities are increased up to 100% at the B lines, then the prioritized vehicles of B line cannot handle the material handling tasks within the time windows. The flexibility of the system (provided by LAP) let the TAS to assign tasks for those vehicles which are prioritized for the parallel (A and C) lines, but some locations at the B line are assigned for them.

The solution possibly makes it possible to operate the system with less vehicles, because we should not dedicate vehicles for the maximal production of every line. It let us possible to reach synergic results of handling global optimum of vehicle scheduling.

3 Conclusion

The proposed paper highlighted the necessity of adaptive line feeding systems and described a promising conceptual approach. This research planned to be continued based on the followings.

Because of the increased complexity of the systems and the several possible solutions any simulation model would be necessary to model, validate and evaluate and prioritize possible material handling and transport procedures. The simulation model would be the tool for the LAP and TAS algorithm development. While the LAP would be used on tactical level and handling within the simulation model can be suitable. While the TAS algorithm should provide low running speed because of the operation purpose, it should be developed as a separated module to be able to connect to IT systems during the integration phase. The high complexity, the high number of possible cases and the low available running time window will might require any meta-heuristics optimization for the LAP and the TAS. The huge amount of data and possible required prediction might require any big data and artificial intelligence technique.

References

[1] R. Baller, S. Hage, P. Fontaine and S. Spinler: The assembly line feeding problem: An extended formulation with multiple line feeding policies and a case study in: *International Journal of Production Economics*, vol. 222, p. 107489, 2020.

[2] S. Emde and M. Gendreau, Scheduling in-house transport vehicles to feed parts to automotive assembly lines in: *European Journal of Operational Research*, vol. 260, no. 1, pp. 255-267, 2017.

[3] A. C. Caputo, P. M. Pelagagge and P. Salini, Selection of assembly lines feeding policies based on parts features in: *IFAC-PapersOnLine*, vol. 49, no. 12, pp. 185-190, 2016.

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