SIMULATION OF LARGE STANDARD STILLAGE PLACEMENT ON A DIESEL-ENGINE ASSEMBLY

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ABSTRACT

BMW Motoren GmbH in Steyr, Upper-Austria is the most important manufacturer of diesel engines in the whole BMW automotive group. A new strategy to enhance the capacity on one of the two assembly lines and avoid problems in room limitation as well an expected potential for optimization of forklift utilization has lead to the development of a new set of modules to simulate the supply of the assembly lines. Within the simulation study, different strategies for order assignment (order dispatching) could be examined. The most important parameters could be identified and their influence on the number of line stops due to missing parts, which means low productivity, could be shown.

INTRODUCTION

The optimisation of mixed model assembly lines by means of discrete event simulation is a well known art. (Banks98), (Fishwick95). Assembling is only one part of the whole manufacturing process. There are many other supporting processes like ordering, delivery, commissioning, supply and finally disposal of waste goods. This is known as the logistics chain. It can be distinguished between administrative tasks (keep all suppliers informed, manage the time table of transports etc.), the so called business-process and the physical processes itself (commissioning, transportation …).

The processes of manufacturing and assembling are, at least in the case of mass production, well defined. Building a model for these processes is therefore a straight forward task, maybe challenging because of complexity or quantity, too. Within the logistics chain many tasks are not described into detail or depend on the human being, who has to make its decisions based on its individual experience and skills. Therefore, accomplishing a task may result in big differences in the way it is done and in the time needed for it.

Some of this uncertainty can be solved by traditional means of modelling, such as using a random value with a suitable distribution instead of an exact value. On the other hand you have to make more assumptions to keep the model simple and to avoid to get lost in details.

SITUATION ANALYSIS

BMW Motoren GmbH is the main manufacturer of 6 cylinder petrol and all 4 and 6 cylinder diesel-engines in the whole BMW automotive group. In 2002 about 561.000 engines have been produced, spread on 326.000 diesel and 235.000 petrol engines.

Diesel engines are produced on two assembly lines. Line 3 is responsible for assembling 20 different types of 6-cylinder diesel engines. It consists of four sections. The first section is built using conventional conveyors. All other sections rely on AGV's to transport the engines to the following station. Line 4, built just in the beginning of this century, uses conventional conveyors for the whole assembly line. On this line, 6 different types of diesel engines are built. Because of the limitation of available room, this line is spread over two floors. It is said, that, in terms of room efficiency, it is one of the most efficient engine assembly lines worldwide.

Within this paper (and the project) the focus is laid on the supply with large standard stillage (LSS) only. Both lines are supplied with material by means of 2 independent lifts. Each of them can deliver goods to both lines. Each line relies on different strategies both for reordering and for delivering requested parts. There is only a minor difference in process flow in the disposal of empty LSS-boxes.

Line 3 has a small intermediate storage in a close range of each assembly station. When nearly empty, a LSS will be replaced with a fresh one from the intermediate storage by a requested forklift. The forklift removes the empty LSS and places the full one at the station. On some stations the forklift has to wait until the last part is assembled and the LSS is entirely exhausted. On the other stations the remaining parts can be reloaded into the new LSS by the worker. This allows the forklift to change immediately without waiting. When the replacement of the LSS is finished, the forklift dumps the empty onto a waste goods trailer. Additionally, the forklift driver is responsible for reordering from the ware-

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house. When, the new full LSS is delivered by the lift it is placed again in the intermediate storage.

Line 4 has two central intermediate storages instead of the individual nearby storages. Filled LSS's are brought to a commissioning zone close to a group of assembly stations. The forklift places the LSS on a special low level vehicle and is immediately ready for the next job. When the old LSS is completely exhausted, it is brought to the commissioning zone by the responsible assembly operator. When returning, he is pushing the LSS on the vehicle to its destination at the station. Now, the forklift has to return to the commissioning zone and dump the emty LSS as described above.

This strategy has been necessary to overcome troubles with limited space for manoeuvring the forklift within the assembly zone. It has the advantage (from the logistical point of view), that the forklift has no need to wait until the last part of the LSS is assembled. The disadvantage is that it depends on free vehicles, whose maximum number is limited due to the restricted space within the commissioning zone. In addition, the assembly operator complains about the extra task of changing the LSS. When requesting a forklift to supply a new LSS from the intermediate storage an order to the central warehouse is placed automatically.

The lines are, although situated side by side in a common building and using common resources like warehouses and lifts, completely differently and independently structured. The assembly and also the logistics personnel are divided into different departments. There is no direct cooperation between these departments. Also the placement of material on the line is performed by different groups of forklifts, who do not support each other (at least officially). Each forklift has a certain job, e.g. maintain a certain section or unload the lift and take the parts to the intermediate storage.

Goals

It is evident, that combining both groups of forklifts can improve security of supply, maybe even with fewer resources. BMW decided to make a simulation study to evaluate possible benefits. The study should show whether:

- It is possible to unite these two forklift groups
- What organisational structures are needed?
- What strategy for task distribution is best?
- How much resources are needed to supply both lines?
- How many vehicles are needed at the various commissioning zones to minimize forklift waiting times and insure zero line stops due to missing parts?

Because of the corporate wide strategy in discrete event simulation, it was a preliminary condition to use the simulator eM-Plant™ (Tecnomatix Technologies Ltd., http://www.eMPlant.com/) for building the model. The model had to rely on only the eM-Plant standard components, and was not allowed to use any AOL's or other commercial libraries.

Assumptions

As stated above, there are many uncertainties and exceptional cases in modelling these processes. Many data needed was not available and even not collectable (e.g. average speed of forklifts) because of legal circumstances. In many situations the staff is able to change the standard processes, e.g. reroute the path to a station because of traffic. The decision of taking another route or wait, maybe just a few seconds until the traffic jam is over, is complex to model. However, for an experienced forklift operator it is simple and rather intuitive. For implementation of a simulation model you need concrete specifications. So we decided to make some preliminary assumptions:

- When working, a forklift does not disturb other driving forklifts.
- Forklifts can only carry one LSS at a moment in time
- All forklifts have the same velocity. There is no need for taking care for acceleration/deceleration because of the usage of a low average velocity.
- There is a strict priority in the timetable-schedule of performing jobs:
    - Refuelling (change batteries)
    - Unload lifts
    - Maintain stations with necessary parts
    - Dump wasted material
- Within the priorities the sequence of orders is strictly chronological
- There is a possibility to order a certain forklift for a given task
- There is no focus on the assembly stations itself. We did not model any failures or maintenance periods. The cycle time is not type dependent. There are no extra buffers between stations. The only failure a station may have is if there is at least one missing part. All failures of this type are to be logged.

THE MODEL

The model was built using the discrete event simulator eM-Plant™ in version 4.6. As we started from scratch, we had to implement not only components for stations, forklifts with order dispatcher, roads, crossings, stores, lifts, dumping, reordering, battery changing but also ”helper” components to increase comfort and efficiency in performing experiments with the model.

According to the assumption, that forklifts do not disturb other forklifts, we built a system of bi-directional roads. We implemented several types of crossings with various numbers of crossing roads. They are needed not only for the road net itself but also in order to approach the stations. We decided to use the standard "automatic routing" capability. Thus it was necessary to implement "Forward destination Lists" for every track within a crossing. Because we had to implement 20 crossings and additionally 120 approaches it was important to create a tool to fill in these lists automatically. As a secondary effect we got a matrix of (shortest) distances between all destinations. This matrix is also used by the order dispatcher when the "find nearest forklift" strategy is used.

Our central order deployment component, the so called "dispatcher" was built as the most "intelligent" part of our model. It can be extended with new dispatching strategies very easily. We implemented simple *First Come First Serve (FCFS)* strategies as well as a more sophisticated *"Find nearest Forklift" (FNF)* strategy or a strategy to ensure almost *"Perfectly Balanced Utilization" (PBU)* of forklifts. These strategies are used for dynamic order assignment. In contrast to these strategies we also implemented a static order assignment. This strategy causes the dispatcher to assign all tasks of a given station to one designated forklift. We used this configuration to model the "traditional" order assignment.

Every assembly station knows about all parts it assembles. It needs type dependent knowledge of part consumption as well as information about the LSS. (e.g. the number of boxes within a station and in the intermediate storage) and about the number of parts within a box. When the content of a LSS is falling short of an adjustable limit, a new order is placed. If there is less than the required amount of parts, a failure is raised. Immediately, the "guilty" part and the duration of the failure are logged. It has been necessary to implement an "Emergency Order" strategy to prevent forklifts of deadlock situations.

For statistics evaluation the forklift utilization is divided into the states *Driving*, *Waiting and Loading* (*Unloading*) and *Free*.

We implemented an "ActiveX" based interface for comfortable key-in in of data with MS-Excel™. This interface is also used for building an "Auto-Experimenter" – a tool which automates the parameterisation and execution of experiments. Tecnomatix delivers newer versions of eM-Plant with a similar tool.

RESULTS

The simulation proofed that the new concept of maintenance for line 4 with vehicle based LSS exchange will work. The necessary amount of vehicles on the commissioning zones could be defined.

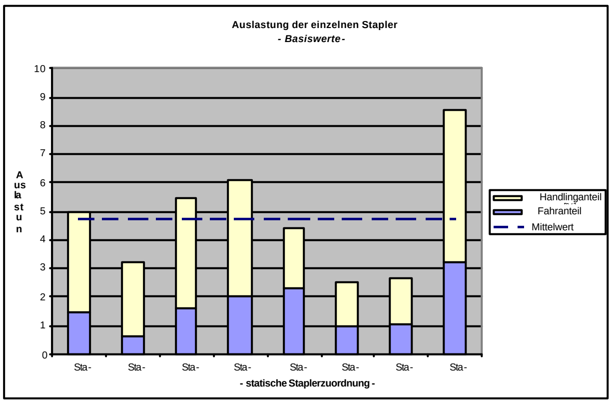

Figure 1: Utilization of forklifts (2 groups, static order assignment)

In our first series of experiments, we examined the influence of different strategies of order assignment. We found that the average value of forklift utilization in standard order assignment (Figure 1) is only marginally higher than in the FNF strategy (Figure 2). (All results shown rely on special, hypothetical conditions).

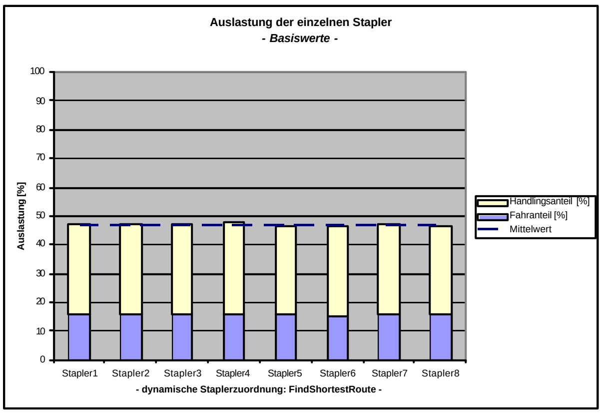

Figure 2: Utilization of forklifts (1 groups, dynamic order assignment (FNF strategy)

This is especially true, when there are few forklifts with an already high utilization. Although it was not in our special intention, all forklifts are almost equally balanced.

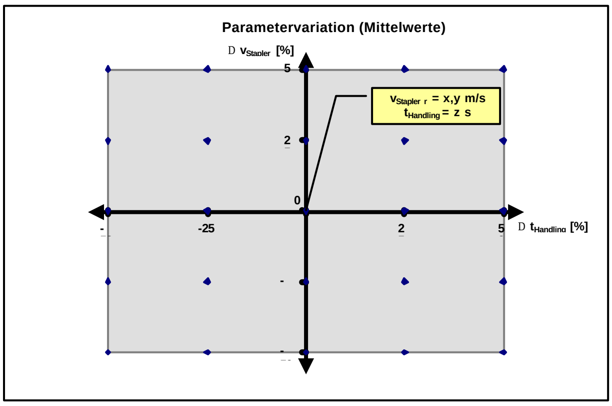

Figure 3: Range of examination: parameter speed and load time

This first experiment showed very different forklift utilization. The diagram reflects the original static order assignment. In reality, there is not such a rigid "demarcation line" between the tasks of the individual forklift. The operators will help each other. This makes the differences in utilization among all forklifts smoother. Furthermore we did not make any effort to improve the balance by reassigning stations properly.

The *FIFO algorithm* takes care for good balancing too, but causes a slightly higher utilization.

The *PBU algorithm* also resulted in higher utilization, but decreased the differences among all forklifts.

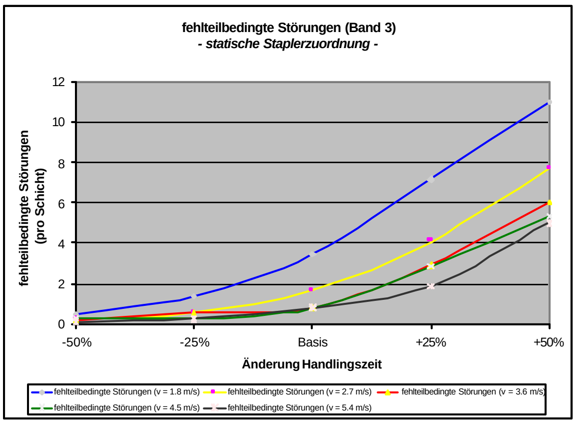

Figure 4: Number of line stops due to missing parts (2 groups, static order assignment)

Because of the measurement of data, such as forklift speed or load time being prohibited, we had to rely on approximations and theoretical computations of an average speed.

Therefore, we made an experiment series to get a feeling for the influence of these parameters. We made an analysis about sensitivity for these parameters by performing experiments on different parameter combinations in a range of +/- 25% and +/-50 % (Figure 3) of the estimated values. We also measured the influence of these parameters on the number of line stops.

In cooperation with the affected foreman, consensus values for forklift velocity and load / unload time finally could be found.

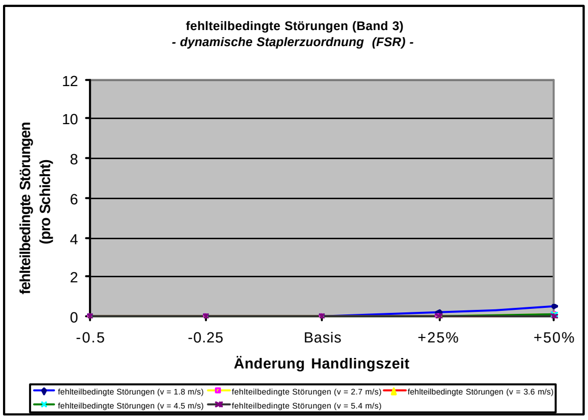

Figure 5: Number of line stops due to missing parts (1 group, dynamic order assignment (FNF strategy)

As expected, the number of line stops increased with the forklift utilization (Figure 4). There was a legible improvement when using the dynamic order assignment (Figure 5). There are almost zero line stops in the whole parameter range.

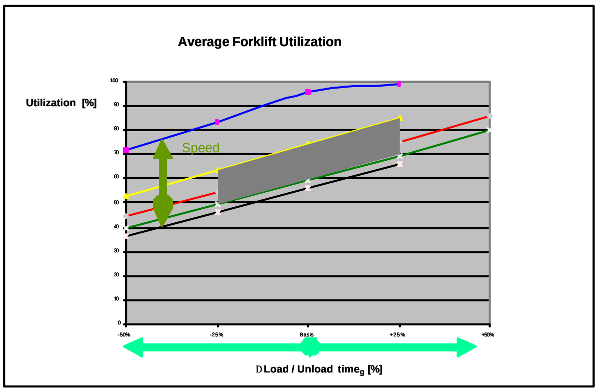

Figure 6: Average utilization (1 group, "FNF" strategy, 6 forklifts)

In addition, we checked the forklift utilization for a different number of forklifts. With an optimistic choice of both parameters (speed and load time) the number of forklifts could be reduced from 8 down to 4. Due to safety regulations and the rather narrow lanes, a more pessimistic set of parameters have been chosen. The computed average utilization with 6 forklifts in use and different values for load/unload time and forklift velocity is shown in Figure 6.

CONCLUSION

Building a model for assembly line supply needs a lot of process knowledge. Many tasks are not defined into detail. The forklift operators usually are very free in determining which task should be performed next. They have little assistance in planning their next tasks. The duration, for both transporting and handling of large standard stillage depends very much from the skills of the operator. Therefore a lot of assumptions must have been made to keep the model "as simple as possible".

In tight cooperation with the forklift operating foreman, feasible and plausible parameter values for forklift speed and load / unload time could be found. The course of events, though simplified, is validated and accepted by the experts.

The experiment results showed that there is no major difference in forklift utilization, when comparing dynamic order dispatching strategies with (well balanced) static strategies. Dynamic strategies have an advantage in scalability and supply guarantee. Of course, there is a need for organisational measures like an additional order dispatching system including technical equipment for communication with all forklift operators.

The study we made lead to (until now) three new projects and each of them extended and improved our set of modules and our know-how in modelling assembly line supply.

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