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DEVELOPMENT OF A DISCRETE SIMULATION MODEL FOR A LIGHT RAIL VEHICLE ASSEMBLY LINE

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Abstract: *To optimize production and assembly lines concerning processing time and work utilization often discrete simulation tools are used. These tools are most common in serial production with high level of automation like the automotive industry. For non common or less automated fields of industry like the assembly of light rail vehicles (LRV) such tools cannot be used without additional efforts. At least standardized functions and subroutines are not functional for the use of productions with high processing times and low units of one type. In this paper several solutions and developments are shown, how discrete simulation tools can be used for the optimization of the LRV assembly*

Key words: *discrete simulation, final assembly, light rail vehicles, processing time, work utilization*

1. INTRODUCTION

To increase the overall efficiency of production and assembly lines with the additional goal of highest added value often discrete simulation tools are used. Such simulation tools mostly are used for serial production like the automotive industry. Therefore several functions and subroutines are defined what makes it relatively easy to create a simulation model and to run experiments. In a R&D project, carried out at the Institute of Production Engineering and Laser Technology of the Vienna University of Technology, the main approach was to optimize the final assembly of a tram production in one site of a multinational operating company. At the beginning it was decided to use discrete simulation to optimize the work utilization, to predict the system output, to define strategies for different scenarios and for decision making processes for extraordinary circumstances. The chosen simulation tool is ARENA 13© (Rockwell Automation) (Kelton et al., 2010). After a short period of modeling it was recognized that some of the standardized functions and subroutines cannot be used for the simulation of the assembly of LRV.

item	Light rail vehicles	automotive
units of one type	< 100	> 20.000
Production of parts	Single part production/small batch production	Transfer lines / production cells
Type of assembly	Shop assembly	Automated assembly line
Assembly staff	Versatile workers	Specialized workers
Learning curve	High influence	insignificant
Influence of changes	High	none
Sequence of production	PULL (backward scheduling) because of product size	PUSH because of fixed cycle time

Tab. 1. Differences between tram and serial production

Therefore it shall be demonstrated how the production of LRV differs from the automotive industry (see Tab. 1). These differences make it necessary to develop new functionalities when using a discrete simulation study for tram production optimization what can be seen as limitation of the research. Another approach was to develop specialized functionalities like:

- modeling the influence of learning and change curve,
- influence of other productions on the same workstations,
- backward scheduling,
- control panel and
- flexible allocation of staff to processes.

2. LEARNING AND CHANGE CURVE

A learning curve means that there is lot more time needed to produce the first units of one type. This time needed gets more and more reduced the more efficient the organization and the workers act (Yelle, 1979). In producing LRV the learning curve is of highest interest and importance because the time needed for the first vehicle is approximately four times longer than the target time. The target time gets reached between vehicle number 20 and 45.

Because nearly every type of a LRV gets especially adapted to the customer’s needs there is always a huge effort necessary for the adaptive design. Not to lose too much time the start of production is quite near or even parallel to the finalization of the design. This results in the request of changes during the production phase. Normally such change requests (CR) are separated into mechanical and electrical CR because they influence diverse departments. CR influence the time needed to work off affected subtasks. All CR can be described via change curves.

Effects, the learning as well as the change curve, are implemented in the model via the possibility to input tables with real values of elongating process target times in the simulation model. Therefore an automated input and output function was developed, which enables to run experiments with different curves just with one click.

3. INFLUENCE OF OTHER PRODUCTIONS

For the assembling of LRV a lot of space is needed for assembly and supply areas. Because of this mostly there is just one type of LRV produced in one production hall. If some kinds of bottlenecks or a temporary overload make it necessary to produce two different types of LRV in the same production hall you do have to implement this in the simulation model. This influence can have different consequences. First the assembly area can be occupied, second the supply area can be occupied and third another production can have influence just on the time needed for one or more processes. All influences can occur independent or in combination with each other.

To simulate the influence of other productions disturbing entities, which are further described more in detail in an assign module via the setting of different variables, are created. Such it is possible to simulate different influences and there consequences in different ways for every single disturbing entity to every simulation time. This functionality can be used for “What if” analysis and to support the decision making process for future purchase order scenarios.

4. BACKWARD SCHEDULING (PULL)

In most of the serial production scenarios a defined cycle time is relevant for all transports and automated production machines. When transferring huge products like parts of LRV there is no automated transport possible. There is always an overhead crane needed and it is has to be ensured, that the target location is empty and ready prepared. This means that a transport of a module of a LRV from one assembly station to another is only allowed when the previous module has left the target location (Spearman & Zazanis, 1992).

When all processes of a station are finished it is checked if the next station is empty. All other restrictions are proved by a variable check. This functionality is as well used for the transfer of LRV modules as for the delivery of parts assembled at one station. Such a PULL production system is simulated.

5. CONTROL PANEL

The developed model consists of more than 1,500 modules and in average every module is defined by six parameters. All together there are more than 9,000 parameters you can change but only 220 parameters are needed to carry out experiments. This is one of the main problems that discrete simulation tools normally only can be handled by experts. If you do not know which parameters are the relevant ones there is nearly no way to simulate the right scenarios in the right way. Furthermore it is another big problem if there is more than one parameter changed from one experiment to the other. Then it will be quite difficult to repeat all done experiments with exact the same parameter setting.

Therefore a control panel was programmed with the programming language "Visual Basic for Applications". This control panel allows the user to manage the most important parameter variations (like available number of workers per station, maximum and minimum values for number of workers per process and target time per process). Further it is possible to store and open different parameter settings and to activate or deactivate functionalities. This panel consists of five tabs, one for global settings and four tabs concerning the four assembly stations in the production hall.

6. FLEXIBLE ALLOCATION OF STAFF

Normally processes as modules in ARENA are mainly defined via the process time. This is the time an entity, which normally represents a product running through the model, is delayed until it leaves the process module and gets transferred to the next module. Additional a process module can seize resources like machines, transporters or workers. The combination of the process time and the seize of resources enables a process time as a function of the number of resources. E.g. the more resources are available the shorter the process delays the entity (Decker & Grösl, 2008). When assembling LRV there are often more than one processes started parallel with one or more workers for each process to reduce the overall cycle time. Because the time to finish these processes is different, after a while there will be at least one disengaged worker. In reality this worker will switch to another process and support his colleagues. Such this second process will be finished faster compared to the situation that the worker had not switched. This procedure is manifest for reality but there is no way to model this functionality in ARENA with standardized modules or functionalities.

To solve this problem a specialized functionality was developed to enable the increase of number of workmen in an ongoing process. Normally the process time as function of the number of workmen is calculated and the longest process time of a group of parallel processes is set as time needed for the whole group. Fig. 1. shows an example of a group of four parallel processes. There are seven workmen available to carry out these processes. A static staff allocation will result in a total time needed of 24 hours and a workmen utilization of 69 %.

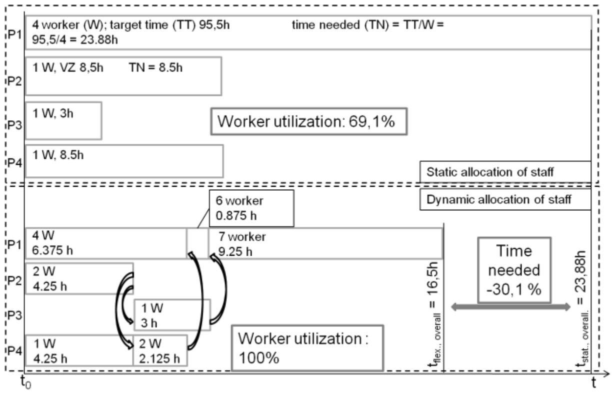

Fig. 1. Example for a flexible allocation of staff

The developed functionality for the flexible staff allocation divides every process into slides of one minute. Every minute there is checked in a loop, if there are still all workmen engaged and if a process is already finished. If one process is finished, all disengaged works switch to another process preconditioned that the maximum number of workmen allows it. Such in our example the time needed can be reduced to -30 % and the utilization of workers could be increased to 100 %.

7. CONCLUSION

The generated discrete simulation model was used for the optimization and analysis of an assembly line of LRV. The specialized developed functionalities enable users of this model to carry our analysis in a level of detail, accuracy and precision it was never possible before for this field of industry. Primary some analyses were enabled via these developments.

In future this model can be expanded from one assembly line to the whole production location as well as other locations of the company.

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