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MATERIAL HANDLING RESOURCE UTILIZATION SIMULATION STUDY FOR STAMPING PLANT

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ABSTRACT

This paper describes the application of dynamic simulation to evaluate material handling resource utilization for a stamping plant in the automotive industry. The other objective of this study was evaluation of throughput relative to press schedules, shift patterns, the number of material handling resources (i.e. fork truck and tugger train drivers), and storage inventory levels. This dynamic simulation study enabled plant managers to balance the driver utilization with respect to time and to accommodate typical press schedules to achieve desired throughput levels.

1 INTRODUCTION

Historically, the earliest and still most numerous applications of discrete-event process simulation have been in the manufacturing sector of the economy (Law and McComas 1998). Recent examples of such simulation use have been documented in (Bandinelli, Iacono, and Orsoni) to manufacture and install large custom-made products, in (Giribone, Mosca, and Queirolo) to validate weekly production schedules, and in (Zottolo and Williams) to improve the manufacture of extruded window seals within the automotive industry. Indeed, most automotive manufacturers use discrete event simulation to verify manufacturing system designs. Use of simulation in manufacturing plants can be classified based on the goal of the simulation study. Four major categories that can be identified in this classification are: equipment and layout design studies, product mix and sequencing studies, labor utilization studies, and variation management studies (Ülgen and Gunal 1998). The stamping plant simulation study discussed in this paper included all four of the above-mentioned categories within its context. However, the main objective of the study was to evaluate utilization of material-handling resources. Stamping plant performance is heavily dependent upon proper scheduling of both equipment and human resources. Scheduling determines the sequence that each machine and laborer should follow in order to meet production requirements. However, the stochasticity of demand makes it almost impossible to follow a fixed scheduling pattern. The dynamic nature of scheduling thus requires plant managers to fine-tune their material handling resources almost daily in order to achieve desired throughput and ensure high resource utilization. Increasing labor costs have only underlined this need further. The simulation model discussed in this paper provided the ability to evaluate contention for resources and indicated when manufacturing lines become blocked or starved due to insufficient material-handling resources. The simulation study thus delivered a simple tool that will be re-used repeatedly in the future by both plant and corporate personnel (hence, both operational and strategic management) to evaluate the impact of changing conditions in the stamping plant on fork truck and tugger train drivers' utilizations.

2 PROCESS OVERVIEW

The scope of the system to be studied includes the primary material movement made by the material control drivers from the blank storage areas through the pressroom lines to the subassembly areas. Material control drivers include both forklifts (Forger 2005a) and tugger (bug) drivers (Groover 2001). The stamping plant involved in this study has several press lines that make the sheet metal parts. Each press line alternates between a "one-out process" (one end product per power stroke) and a "two-out process" (two end products per power stroke) depending on the part that it produces. Sheet-metal parts are stacked onto the part racks. These part racks are of widely varying capacities, partly because the racks themselves are of different physical dimensions, and partly because the large variety of parts they must carry are of different sizes. At one extreme, only nine or ten parts may fit on one rack; at the other, several hundred will fit on a rack. The client was eager to explore the relationships between part density per rack and material-handling resource utilization. Furthermore, since nearly every part has its own rack specifically designed to transport it, the large number of racks in and around the facility represents over two acres of space. Since some of this space is in an outdoor rack yard, material-handling resources spend significant time moving racks between the rack yard and the plant as required by production. The transport of racks between press lines and several subassembly lines that build subassemblies to be used in the downstream assembly plant is performed by a combination of manually operated fork trucks and automated equipment. In addition to pressed sheet-metal parts, subassembly lines also require purchased parts that are moved by indirect (subcontracted) labor. Both press lines as well as subassembly lines follow dynamic, line-specific shift schedules. Part racks are either routed to subassembly lines directly or stored in the temporary storage location depending on space availability and flow logic. Each part rack is assigned a primary storage location as well as a secondary storage location. Part racks are routed to the more distant secondary storage location if the primary storage location has insufficient space to accommodate them.

3 MODEL ASSUMPTIONS AND MODEL INPUT

3.1 Modeling Assumptions

In accordance with rigorous simulation-analysis practice, all the following assumptions were documented after concurrence between the analysts and the client: (Chung 2004).

- Secondary storage locations have infinite capacity.
- Storage area capacity is defined as net space available (gross minus any staging space and cubing inefficiencies).
- Unplanned downtimes are excluded from model.
- Die set changeover, or run-to-run time (rtr), are specified by press line.
- The cycle time for Fork/Tugger does not change even if the racks lifted are less than its maximum capacity.
- Parts per trip for the fork truck delivering blanks to the press should equal or exceed parts-per-rack of the respective part.
- If a press is unscheduled for a particular hour and it has generated insufficient parts to fill a complete rack, then it will continue until the partially full rack has been filled and then stop for the remainder of that hour.
- Blanks, empty racks, and purchased parts are always available.
- Blanks are supplied to the presses assuming that both the “one-out” and “two-out” processes need just one blank to stamp the required parts.
- Available time per shift is approximately 7.2 hours to account for lunch and breaks within an 8-hour shift. The actual shift schedule provided by the plant will be applied to both the pressroom and the subassembly area.

3.2 Simulation Inputs

The following is a list of input data required by the model.

- Sequential schedule for each press line including cycle quantity and press rate.
- Production rate for each subassembly area.
- Shift schedule for pressroom and subassembly area.
- List of all drivers.
- Driver used for each move.
- Rack densities for all part numbers included.
- Routing and time requirements for each move from press to storage and storage to subassembly.
- Containers per move.
- Storage location capacity.
- Primary and secondary storage locations for press parts.

A Microsoft Excel® workbook was developed to store model input. These data were read directly by the model – a valuable impetus to the ultimate self-sufficiency of model usage and understanding aspired to by the client (Williams 2003).

4 MODEL CONSTRUCTION, VERIFICATION, AND VALIDATION

The simulation model was built using the WITNESS® simulation software package (Mehta and Rawles 1999). This package is relatively easy to use and contains numerous constructs for modeling significant components of the actual system, such as fork trucks, machines, work shifts, and operators.

The intent of the baseline model was to capture the utilization of the existing drivers that service the end of the press line in the press room given a typical press schedule. The modeling analysts used various techniques to verify the model. These techniques included structured walkthroughs, extensive use of simulation traces, and observation of the animation whenever deemed necessary. Plant engineers and the simulation analyst worked together to validate the model. Validation techniques included Turing tests, degenerate tests, extreme condition tests, fixed value tests, and historical data validation (Sargent 2004). Since the planned usage of the simulation model included running it daily to choose and assess production plans, the model was built to execute quickly (within 10 minutes) on a Pentium 4 (2.8 gigahertz) with 512 megabytes of RAM.

Therefore, instead of using the "tracks and vehicles" constructs of WITNESS, the model was constructed to use variables to track many material-handling performance metrics. Some of the knottier errors unearthed by the verification and validation techniques originated within this usage of variables, many in subscripted arrays. The baseline model was run for a period of 240 hours to ensure a mix of part numbers running on different press lines at different points in time.

What-if scenarios were run after achieving the credibility of the baseline model by applying the aforementioned validation techniques. Final recommendations were submitted after careful analysis of what-if scenarios with the client.

5 MODEL RESULTS AND CONCLUSIONS

The following is the list of output values reported by the model.

- Total number of moves.
- Total time for moves.
- Driver utilization as a percentage of available time.
- Time and product running if press room is stopped due to lack of material handling resources.
- Storage location utilization.
- Subassembly as well as press line throughput.

All output from the model was written directly to Excel® for ease of examination, further plotting, export to Minitab® for statistical analyses, and incorporation into PowerPoint® presentations.

Output from the baseline model is shown under two situations: First, only one part number was run on each press line. This part number represented the "worst" case for the end of the press line material handling drivers since their utilization is the highest for that part in the schedule. Second, all the part numbers were run on a press line following a typical schedule to show the variability in driver utilization over the course of a typical schedule.

A key output from the model is a graph of the utilization of each driver group by hour to show the variation of driver utilizations over time. Sample model output for the "Hi-Lo" driver group servicing Press Line 2 is shown in Figure 1 at the end of the paper.

What-if scenarios were run to better understand the benefit of utilizing a team-based approach where material handling drivers can share more duties across press lines. Creating teams that share duties across press lines tends to smooth out the utilizations of drivers. The team-based approach assigns each driver to a team, versus the current method of pulling from a pool of drivers.

Changes were made to the baseline material-handling assignments such that a driver team could handle any press parts coming off the line when running a typical schedule. A critical requirement was that the new driver teams should collectively be capable of preventing blocking of or stopping the press lines. Additional travel time had been added in the what-if scenarios to account for travel time between lines when a driver covered more than one press line.

It was shown that not only does the team-based approach reduce the number of drivers from 35 to 27, but also it helps increase driver utilization from 38.2% to 49.5%. Since eight fewer transport vehicles were likewise required in simultaneous circulation, client managers eagerly embraced the enticing possibilities of lowering fleet maintenance costs and gradually "retiring" some capital equipment. Energy costs also took a welcome downturn, especially for the tuggers, which run on liquid propane gas [LPG] (the forklifts run on electricity, and hence consume some energy even in standby mode). The latter figure closely matched a long-standing management aspiration: at approximately ½ utilization, drivers are not excessively idle, yet readily available for other duties such as clean-up, general maintenance, certification, and quality inspection. This gentle expansion of drivers' job duties reduced daily tedium and gradually came to be positively perceived as improving the drivers' working conditions and opening other job classifications to employees wishing greater job-rotation opportunities. The graphs at the end of the paper (Figures 2 and 3) show the advantage of this team-based approach. In keeping with these considerations, the average efficiency shown in the graphs is for moving parts at the end of the press line and excludes these miscellaneous duties.

6 SUMMARY

Utilizing the team-based approach smoothes out driver utilization and requires fewer total material-handling resources to accommodate a typical press schedule. Since drivers are assigned to a team and not pulled from a pool, semi-permanent assignments are established. Because the team-based approach is a substantial change from how the plant operates today, it was recommended to initiate the approach starting with one team so that logistical and interpersonal issues could be addressed and the approach could be fine-tuned; psychologically gradual introduction of new work arrangements is often the difference between success via acceptance versus failure via rejection (Cammarano 1997). Drivers would need to operate as a team and the entire team must take ownership and responsibility for servicing their lines. The importance of attention to interpersonal as well as analytical considerations, all too often neglected in industrial-engineering analyses, is abundantly illustrated in the decision-aid model documented in (Andriamasinoro et al. 2005). With this importance in mind, the pilot team chosen to introduce the new arrangements of work was chosen to comprise experienced workers held in respect by both their managers and their co-workers. As has been documented repeatedly both in the literature (Stern and Aronson 1984) and in the authors' own practical experience, a "new way of working" introduced via respected colleagues has a much better chance of smooth acceptance versus sullen, passive resistance. Furthermore, the simulation – and particularly its animation – demonstrated that the team-based approach was an improvement in resource utilization over having drivers dedicated to one press line. With dedicated drivers, if a given press line switched from low density parts to high density parts, a driver may go from being relatively busy to relatively idle. However, with a team-based approach spanning several lines, if a press line switched to a high-density part requiring fewer rack moves per time unit by the material handling resources, the team drivers could move to other press lines with higher current material handling requirements. The simulation assisted in determining the appropriate team sizes that accommodated the press lines running a typical schedule. Appropriate team sizes were determined such that team driver utilizations fell within an acceptable band of utilization (neither too busy nor too idle).

Creating larger teams that cover more lines could further improve the average efficiency of the drivers. However, the logistics of covering more lines becomes more complicated. The use of call mechanisms, such as lights at the end of each press line, may facilitate creating teams that can effectively cover more press lines. All these enhancements await study in planned follow-up work. Hence simulation certainly proved of very high value to this client due to its ability to both suggest and evaluate changes in operational methods in lieu of burdensome capital-equipment expenditures (Trebilcock 2005). Additionally, the results of this simulation analysis have supported reliable implementation of consistent, continuous material flow by removing people and resources from the process (but in a positive career-path way of alternatives), and while reducing buffer sizes and thereby avoiding an originally predicted need for more building space (Forger 2005b).

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APPENDIX: TRADEMARK

WITNESS is a trademark of the Lanner Group.

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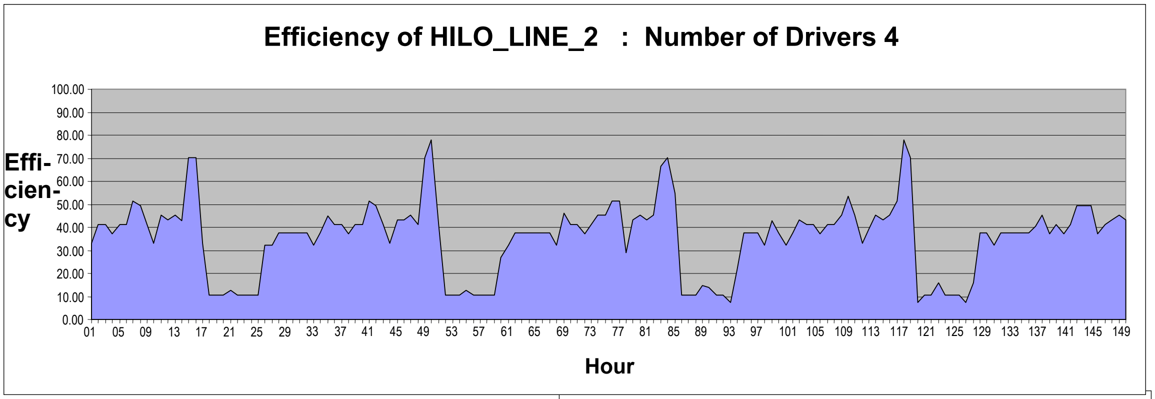

Although Press Line 2 has 2 base drivers, currently up to 4 drivers may be used to service Press Line 2 for worst-case parts

Figure 1. Efficiency of hi-lo Line #2 (servicing press line #2) with two or four drivers

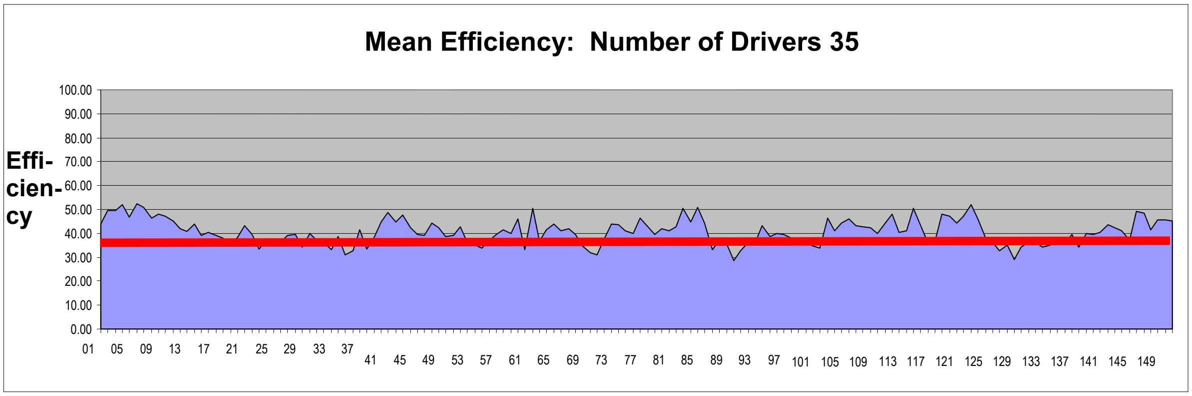

Figure 2. "Before" 38.2% efficiency of drivers (not divided into teams)

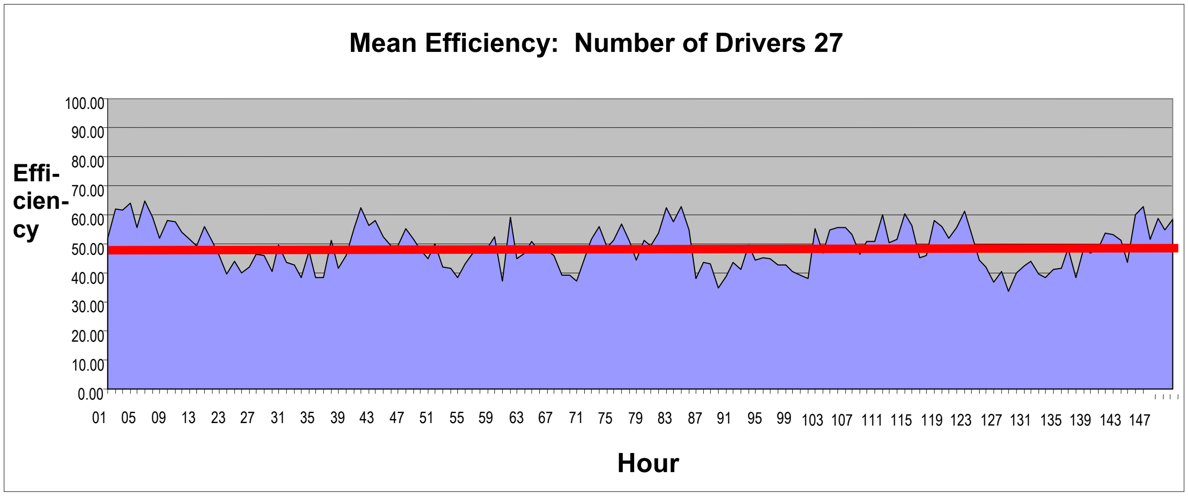

Figure 3. "After" 49.5% efficiency of drivers divided into teams