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SIMULATION IN DAILY FACTORY OPERATION: 'SETTING THE LINE BOGEY IN AUGUSTA'

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ABSTRACT

The John Deere Augusta Works uses discrete event simulation in predicting assembly line output as a function of varying model and option mix quantities in daily production schedules. The most unique aspect of this application is not necessarily how it is used but who uses the model. Prior to each production day, a Union representative executes the model, and the simulation results establish the target production goal for the day. Day-to-day wages are based on the actual production attained relative to the simulated target. This paper describes the simulation tool structure designed for Augusta, and discusses the circumstances surrounding this unique simulation application. Included in the discussion are the benefits derived from the application; the critical success factors enabling its use; lessons learned in converting a simulation analysis into an operating tool; and future improvements envisioned.

1 BACKGROUND

The John Deere Augusta Works started production in 1991 assembling compact utility tractors for the North American Market. The original factory design criteria called for low production volumes of a small number of simple tractor models. Since then the market for this tractor class grew in size and complexity. In 1996, a classic simulation analysis (Schriber and Brunner 1999) of Augusta's factory operation was requested to analyze equipment modifications necessary to accommodate a new tractor product program. For this analysis, a model was constructed of Augusta's paint system and two assembly lines using Wolverine Software products: GPSS/H simulation language (Crain and Hendriksen 1999) and Proof animation (Hendriksen 1999). The analysis identified two process restrictions hampering the desired production volumes. The first constraint involved the paint system capacity; the second was a large amount of blocking delays along the 5000 series assembly line, caused by wide variations in the work content of the scheduled models and options.

A new conveyor design was established and implemented to accommodate the new product program and solve the paint capacity issues. However, the line interference problems on the 5000 series line still existed. To fully understand the delay problems, special simulation measures were devised to qualify the impact of these delays as a function of tractor models and options lineups. At the conclusion of the equipment installation phase of the project, Augusta was provided with a 'runtime' version (see description below) of the simulation/animation program to continually monitor the delays and gain insight into possible solutions. Shortly thereafter, Augusta's front line production support staff began using the model daily to predict line output given the current production lineup of model and options, the work measurements of the different tractor models, and the deployment of assembly technicians. The simulation output became the basis for the daily wages paid.

Since then, the simulation has undergone numerous enhancements turning it into a viable means of equitably determining wage earnings.

2 APPLICATION DESCRIPTION

Augusta's simulation operating tool (Harrell and Hicks 1998) consists of four major components: an Excel user interface; 'runtime' version of the GPSS/H simulation logic representing the Augusta factory; 'runtime' version of the Proof animation of the system and customized output report of the system performance. A diagram of tool structure is shown in Figure 1. Detailed description of the four major components and the process sequence follows:

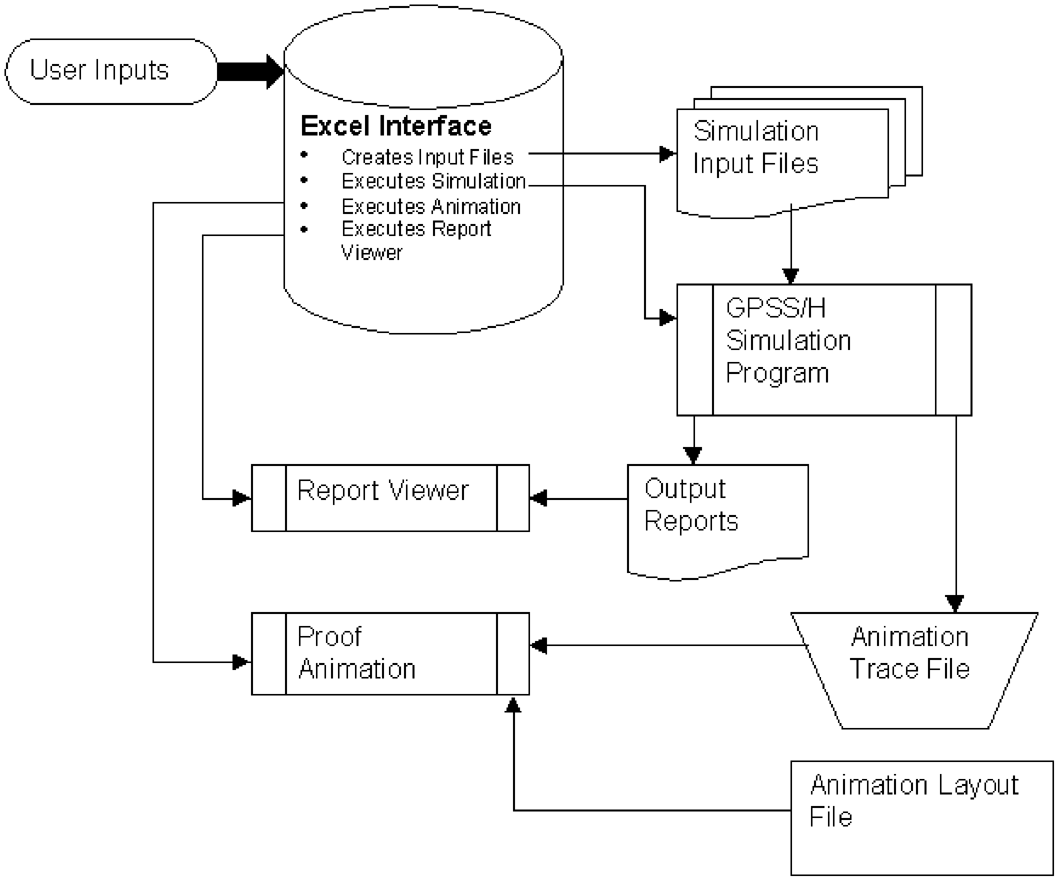

Figure 1: Structure of Augusta Operating Tool

2.1 Excel User Interface

The Excel interface serves as a control program directing all aspects of the simulation use. Data contained in the Excel spreadsheet defines a comprehensive set of production and equipment information necessary to specify a detailed production scenario. This information is logically organized into Excel worksheets and includes the following user defined inputs:

1. General Information documenting test scenarios
2. System and Equipment specification such as the number of power and free conveyor carriers, and the number of assembly carts available per assembly line
3. Daily Production Lineup per Assembly Line describing the individual tractor configuration (model type and options) and the order in which these machines will be processed through assembly
4. Initial conditions of the assembly system
5. Cycle Time work measurement by operation for each model and option type
6. Technician Operating Schedule detailing the effective available working minutes/shift and accounting for periods of technician inactivity
7. Technician deployment assignments determining the number of technicians/shift and their individual operation assignments

Once the user specifies the above inputs, embedded Excel macros execute all the necessary analysis functions, including:

1. Create text files linking the Excel inputs to the simulation
2. Execute the GPSS/H simulation
3. View the Proof animation
4. Display Quantitative Simulation Output Report

The Excel interface provides a single point of control of all the tool functions, making the background execution of the simulation and animation ‘transparent’ to the user.

2.2 Runtime Simulation

The engine behind the Augusta Operation Tool is a GPSS/H simulation model. After the model was written, verified and validated, a 'runtime' object module was created for Augusta. The 'runtime' object feature of GPSS/H enables Augusta to perform repeated data driven simulation tests without depending on an expert simulationist. A 'runtime' license is a fraction of the cost of a full-featured GPSS/H license, and provides the added advantage of leveraging an expertly developed model without burdening the user with constructing the model logic.

2.3 Runtime Animation

Similar to 'runtime' GPSS/H, the 'runtime' version of the animation software enables Augusta to view an animation of their most recent test at a fraction of the cost of full-featured Proof license.

2.4 Output Report

Perhaps the most critical element of the Augusta Operation tool is the output report summarizing the quantitative statistics generated by the simulation. The report was a result of a joint effort between the user and the developer to create a report easily understood and interpreted by the user. Without such a report, this effort would not have been possible.

2.5 Process Sequence

Augusta follows this sequence in using this operation tool:

At the end of each production day, a Union representative downloads the next day's production lineup from Augusta's network. This lineup reflects market demand for specific tractor configurations, and a production scheduler determines the actual sequence.

The Union representative manually verifies the lineup vs. the physical tractors on the line and notes the exact location of the machines in process.

Those noted machine positions are input as initial conditions to the simulation along with the downloaded lineup. Any other needed changes to the Excel inputs, such as special operating schedules, or technician assignments, are made at that time.

The simulation is executed, and the results are posted as the next day's production target. Wages paid for the day are relative to how close the actual production meets or exceeds the simulated target.

3 BENEFITS

A number of benefits have resulted from the Augusta exprience:

1. Increased Productivity. Prior to the use of the Operating Tool, production target was a fixed number based on a weighted average of the work content of an estimated model and option mix. The target did not dynamically reflect daily variations of the actual lineup. Not surprisingly, production output rarely exceeded the fixed target, and many times the output fell short when daily lineups included a high percentage of heavily optioned tractors with large work content. Since the tool has been implemented, daily production achieved has reached as much as 25% more than the fixed target method on days when the work content of the model mix is 'light'. Likewise, the target is reduced under heavily optioned lineups. The use of the operation tool has fostered a more consistent daily effort on the part of the wage staff at Augusta.
2. Increased Awareness of Cause & Effect Relationships. Augusta's frontline support personnel intuitively understood the cause of most of the growth problems experienced. However, many of these issues were difficult to quantify prior to simulation. As a result, the simulation served to reinforce as well as expand much of the intuitive understanding that existed in Augusta. This increased understanding has manifested itself in terms of greater focus on product variation issues in the planning for future assembly lines, as well as raising issues with 'design for manufacture' opportunities.
3. Better Leverage of Simulation Developers. The application of the 'runtime' software features has increased the effectiveness of scarce simulation development resources. By placing the analysis phase of a simulation project in the hands of the user, the developer's time is freed for other applications. Each application results in new lessons learned that can be further leveraged into even better applications in the future.
4. Increased Credibility of Simulation Analysis. Actively engaging operations people in the use of simulation, educates factory personnel in the value of simulation, Any skepticism that may exist about simulation analysis is reduced. Future simulation studies will be more readily understood and used.
5. Cost Effective Analysis. In addition to the cost savings attributed to 'runtime' application software, the return of simulation analysis is greatly enhanced when it can evolve into an operating application from a conceptual analysis.
6. Future Leverage of Augusta Experience. Augusta was the first Deere factory to employ discrete simulation as an ongoing operation tool. This experience has set the standard for all subsequent simulation applications.

4 CRITICAL SUCCESS FACTORS

Obviously a simulation accurate enough to even consider setting the wage base for over 60 people requires significant simulation tools and talent. However, tools and talent alone are not enough. At Augusta, a number of factors converged to turn an ordinary simulation analysis into a unique operation tool. These factors included enabling technologies, Augusta commitment, and Union buy-in.

4.1 Enabling Technologies

Two software applications enabled this project to proceed: 'runtime' software and Excel.

The 'runtime' feature of the Wolverine Software products provides a perfect fit for the John Deere simulation culture. Our new factories like Augusta have small multi-functional staff unable to maintain simulation expertise because of time constraints. Most have no interest in building simulation models, but as evidenced by Augusta, are more than willing to use credible models.

The 'runtime' feature enables Augusta to execute their own data driven simulation tests at a fraction of the cost of a full-featured simulation license. They have no ability to change the core logic of the simulation, but they have no desire to anyway. As a result, Augusta pays only for the functionality it needs. Augusta is still dependent on corporate for logic updates, but are in complete control of tests they run. This proves to be an effective approach for operation/production personnel to engage in simulation.

The 'runtime' software cannot work without some means of data input. For this purpose, Excel was chosen. In addition to leveraging common tools already in use at Augusta, using Excel as a user interface created an immediate comfort level and acceptance of the operational tool. This acceptance facilitated the tool use. With Excel as the user interface to the 'transparent' simulation and animation 'engines', an effective operation tool was formed at minimal cost and consistent with Augusta's computing tool set.

4.2 Augusta Commitment

No project can proceed without commitment and risk. After implementing the paint and assembly additions for the new product program, Augusta was left with a 'runtime' application of the simulation used in the planning. On their own initiative, Augusta began using the application as described in Section 2.5. Since the original model was not designed for this purpose, additional model capabilities were added. Throughout, Augusta stuck to its original commitment and guided the improvements required.

4.3 Union Buy-In

The most remarkable aspect of this project is the execution of the simulation by Union personnel. Without their representation, it is highly doubtful that this application would have been possible.

5 LESSONS LEARNED

The experience at Augusta has become a template for similar applications throughout Deere. With it come lessons that will be carried forward:

1. Documentation. Creating operating applications from simulation causes an added emphasis for documentation. This is particularly important when transferring the model to new people. Even though documentation is a 'mind-numbing' task, few pay more dividends in avoiding misunderstanding.
2. Training. Similar to documentation, providing adequate user training fosters model credibility and continued use. Fortunately, when the application is focused, and the user has a vested stake in the results, adequate training can be quickly accomplished.
3. Continuous Improvement. No simulation is ever really complete. As conditions change, regular monitoring and model enhancements are needed to stay current and credible.
4. Refocus of Objective. The Augusta application addresses specific product growth issues relative to their physical assembly line capabilities. The objective of this operation tool evolved into an equitable payment measure. For future application, creating a simulation for purposes of a pay plan is not recommended. Instead the objective of similar simulations should be focused on adjusting parameters to maximize outputs, rather than predict output as a function of model mix, with all other conditions fixed. New applications, including Augusta expansion plans, will contain this objective.

6 FUTURE ENHANCEMENTS

As the Augusta application evolved numerous opportunities for improvements were identified:

1. Direct Link to Production Lineup. Currently a download from the network, and insertion in the Excel interface is required.
2. Loading of Initial Conditions. This currently requires a physical check of the line identifying tractor position. The same function can be

accomplished by a connection to the assembly line PLC (Programmable Logic Controller).
3. Dynamic Retrieval of Tractor Configurations. Currently, all model configurations in the lineup are equated to one of fifty standard configurations and their corresponding work content. By dynamically retrieving/calculating the work measurement for each configuration, the accuracy would be refined on those unusual configurations, which today are approximated.
4. Embedded vs. Linked. The future of production simulation tools lies in embedding within other production software vs. merely linking.
5. Convert to SLX (Simulation Language eXtensible). To accomplish the above enhancements requires a conversion to the Wolverine Software's new simulation language SLX (Hendriksen 1999), which has the needed ODBC (open database connectivity) and DLL (dynamic link library) functionality.

7 SUMMARY

The Augusta operation tool was a breakthrough for Deere proving that discrete event simulation can be successfully used as a factory-operating tool. What made this project particularly unique, was the involvement of Union personnel to execute the daily tests. While the objective focus will be adjusted on future applications, the basic concept invented at Augusta will continue.

Several valuable lessons were learned in the implementation and use. Among these lessons were: importance of documentation and training, need for cost effective simulation software, the critical nature of Union buy-in, the tool acceptance through familiar user interface, and the benefits of linking available production data.

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Jan McAlpin	5000 Line Supervisor
Glenn Hutchens	4000 Line Supervisor
Brian Biles	5000 Support Engineer
J. Neil Britt	4000 Support Engineer
Sam Peery	5000 Line Supervisor
George Reckentine	5000 Union Representative
Jerry W. Smith	5000 Union Representative
Karl Halmstad	4000 Union Representative
Don Corbitt	5000 Product Unit Manager
Steve Johnson	4000 Product Unit Manager

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