SIMULATION-BASED DECISION SUPPORT SYSTEM FOR AN ASSEMBLY LINE

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ABSTRACT

An application of simulation in the ship building industry is presented. The model is part of the decision support system designed and built to help the programmers develop both weekly and long term assembly plans. The DSS is a mixture of spreadsheets and a simulation model where the worksheets act as the interface between the factory database and the model. A simulation optimization methodology that includes expert input to provide a robust initial solution is also incorporated into the system. The paper presents as well how the different knowledge groups (simulation specialists, production planners, in-house system developers, plant and factory managers) interact in the development and the maintenance of the application.

INTRODUCTION

The competition in the ship building industry is furious, and the structure of the industry in Spain is old both in terms of technology, information management, and personnel.

Therefore, there is a need to update the systems to the new information era. Acquisition of new robots to increase throughput, development of new software to speed the decision making processes, training of personnel to improve the production process... They are all directions of improvement that are necessary to compete and that converge in the representation of knowledge in models to facilitate the decision making processes of the company.

In particular, there is the need in this Spanish factory to incorporate into a decision making tool the knowledge of the production planners to reduce the necessary time to develop the weekly production plans. Moreover, the introduction of new equipment has made the management believe that it was the proper time to incorporate the new plant layout into a simulation model along side the electronic knowledge obtained from the planners. The outcome has been a decision support system (DSS) that proposes production plans that result in a reduction of the total time to assemble the ship. Shorter lead times mean cheaper ships and the possibility of competing in the international markets.

THE SYSTEM

Let us start with a brief description of the operations performed in a specific production line to obtain the two parts in which a given unit or block is divided. The unit is called “sandwich” since it has a double layer of panels with support bones in between. The bottom layer (see Figure 1) is a series of panels welded together in which the bones are inserted and assembled. The top layer has nothing attached but is a similar welding combination of individual panels. It should be noted at this point that the final assembly of the ship is performed outside the specific plant of the factory being studied in this analysis.

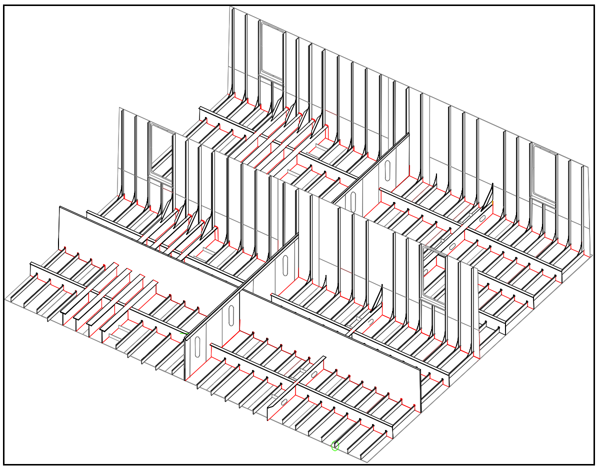

Figure 1. Bottom Part of Block

The plant has a long linear layout in which panels are first prepared before starting the assembly processes, which are divided into two groups (see Figure 2).

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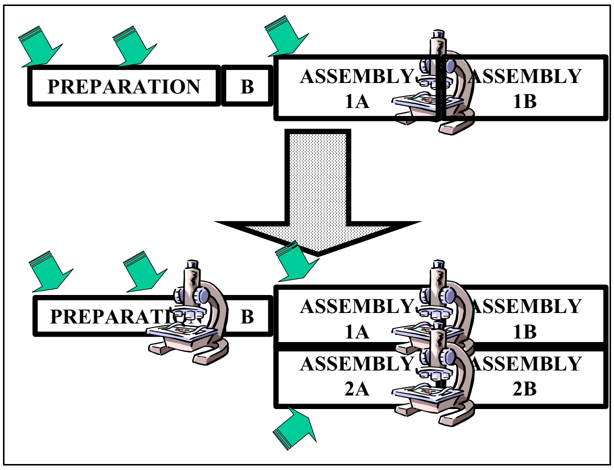

Figure 2. Changes in Layout

In the preparation phase, there is a huge transload that helps move the panels through different cutting and shaving operations, which are performed in the floor over rails. The operations might be manual or automatic, with two points of entry for raw materials. The panels are welded together to the right dimensions and then stored in an intermediate buffer. The exception is that the top layers of the sandwich are at this point removed from the line and stored until the bottom layer is assembled.

In the assembly phase, with four lines, the first part of the line, up until a big welding robot (part A), is used to assemble the bottom layer of the sandwich, inserting the bones (another entry point). Then, in the second part of the line (part B), is where minor welding is manually performed along with the necessary quality assurance checks.

In Figure 2, two different layouts are presented. The first layout includes the old layout whereas the second layout corresponds to the actual distribution. The change is due to the acquisition of a new robot that improves the throughput of the preparation line. Then, to improve the total number of sandwiches assembled, and having enough space and money, it has been possible to duplicate the second part of the process.

THE DECISION SUPPORT SYSTEM

Due to these layout changes, it was the proper time to come up with a robust tool that helped the weekly planning of the line. The managers then launched the project of developing a simulation-based decision support system for the assembly line of sandwiches as a trial version for developing one for the whole factory.

The implementation of the DSS involved the combined work of four main groups: management, production planners, simulation specialists and system developers. The first and important step was to define the tasks to be performed by each group and all the possible interactions (see Figure 3).

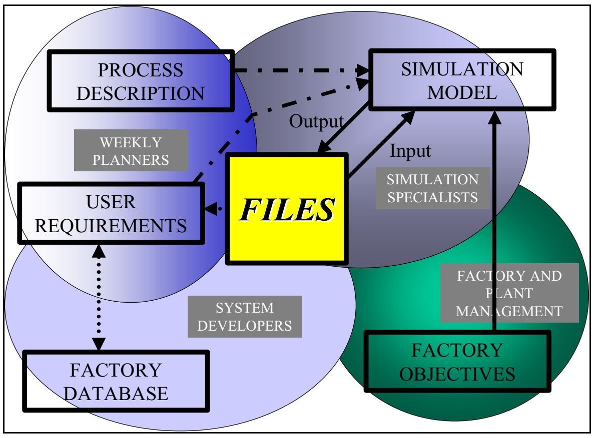

Figure 3. Implementation of the DSS

The production planners had to perform two complementary tasks. In order for the simulation specialists to create a simulation model, they had to put into words all of the knowledge they had not only in terms of the description of the necessary small tasks to assemble the product, but also in terms of the algorithm they use to develop the weekly plan. As it turned out, this last step was critical as it had more assembly restrictions than previously foreseen. Also, as final users of the software application, they had to define the charts and output lists they will be using in the line: Gantt charts, requirements of raw materials…

In terms of the software development, two different groups performed the work. On one side, the factory systems development group was given the task to generate in simple files all the necessary information to manage the line: process times, the production orders, the shifts… They had to combine the information coming from engineering with the one coming from labor unions, and also with the one coming directly from the line. They also had to create the output reports needed by the final users, taking as a primary input the information and the reports that come from the execution of the simulation model.

So, on the other side of the files line, the simulation specialists had to develop the model so it correctly represented the system. Also, the model had to take the necessary values from the files produced by the system developers to generate a set of files with all the necessary output values to produce the plans.

Management, besides overlooking the whole process, also had to set the objectives of the production plan, which are not just the ones of the plant in hand but of the whole ship building factory. The main criterion is obviously the lead time or time to assemble all the orders, but there are some competing criteria like assembling the top part of a sandwich immediately after assembling the bottom part or balancing the two assembly lines. Plant managers had also the important task of maintaining the DSS.

The interaction was in this case between management and the simulation specialists in that the simulation model should present an optimization shell to look for a satisficing solution. Several production plans are to be automatically proposed by the shell and run by the simulation model in order to evaluate the criteria for each plan, compare the plans and select the most appropriate one.

Since any discrete optimization procedure is combinatorial in nature, not all the possible plans might be simulated. Only a small subset is to be run, so it is important that one satisficing plan is included. In that sense, it is well known that the optimization algorithms heavily depend on the selection of the initial trial of the search (Shelokar et al. 2004).

The production planners had at this point something to say as experts. By providing insights about the restrictions on the sequence of orders or the way they are producing the plan, an initial feasible solution is generated, which means that not only a good starting point is known to start the search, but also that at least a feasible solution is going to come out of the optimization routine.

Then, a sound optimization routine might be developed by the simulation specialists, coupling the experts knowledge with management requirements, as well as some production control theory that might come from any of the groups involved.

It is therefore important that the simulation specialists also have a good engineering knowledge to not only program the simulation models but also help in the development of the optimization shell. In this particular case, an according to management's main objective of minimizing lead time without incurring in delays, the shell tests plans in which a combination of production variables like slack, tardiness and criticality (Bedworth 1987) is included in the search algorithm to run in the available search time, only a subset of feasible, satisficing plans.

So, as it turned out, and it is clearly shown in the interactions diagram (Figure 2), in order to bring all the skills and expertise of each of the groups and develop a sound and robust application, what is crucial is the detailed definition of the common files, which are just Microsoft Excel and plain text files. The factory developers stand on one side of the line, the simulation specialists in the other, and the managers and the planners indicating what should be included in the DSS to manage the factory.

THE APPLICATION

The decision support system has been developed using the ODBC possibilities between the MSExcel spreadsheet and WITNESS simulation software.

Three files are needed to run the application:

- The spreadsheet that includes all the input and output files
- The simulation model
- The ASCII file that contains information about shifts

The execution starts in MSExcel when the appropriate button is clicked. The spreadsheet calls the simulation model which, when appropriate within the run, reads the values from the MSExcel spreadsheet called "WITNESS input" and from the shifts file. The search for the satisficing plan then starts. At the end of the run, the simulator writes the output values into the spreadsheet, which regains the control of the DSS (see Figure 4).

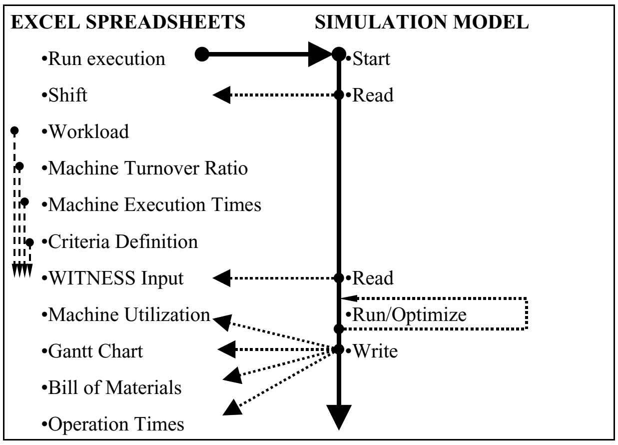

Figure 4. Execution of the DSS

What follows is a more detailed description of each of the parts of the DSS.

Input Files and Worksheets

The MSExcel spreadsheet contains different worksheets that are required by the simulator at run time. These worksheets might be manually or automatically updated by engineering or by the production management itself.

The Execution Screen

The user interface is just a very simple screen (Figure 5) in which the user (the production planner) fills in the necessary information and clicks on a button to execute the planner based on the simulation model.

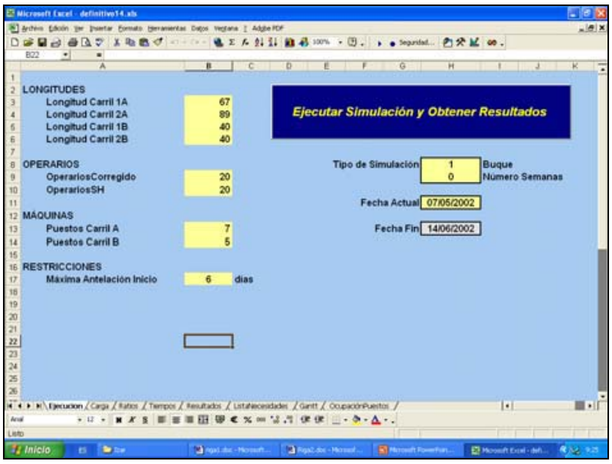

Figure 5. Front End

The information relates to the date in which the program is being executed and the length of the planning period, that could be set for a number of weeks or for the total number of orders to finish the whole ship.

It also includes a set of tactical variables that might be changed if the layout or the staff changes. The length of the lines might be modified as well as the number of its processing stations. The number of operators at each group of stations might also be altered.

Shift
It includes information about the time in which the operators are available. The information is filled automatically from an in-house application developed by the software developers of the company.

Workload
This spreadsheet contains the information about both the orders that are pending and those that are already in progress at the beginning of the simulated period. For each one, there is a description of its physical characteristics, like dimensions and weight. The data is also automatically updated by the information system of the company through yet another in-house developed application.

Machines Turnover Ratio
For each of the stations, this spreadsheet contains a table of velocities that depends on the number of operators that are working on a given unit and the characteristics of the unit. The tables are manually updated since they are constant over time. In case a change must be made the factory management should do it.

Machine Execution Times
Each of the operations performed at one particular machine have been subdivided into several tasks. This spreadsheet contains the setup and execution times for each task. The values are not likely to change so the factory management manually includes them. Some of them are not constant but depend on the characteristics of each unit, so they are not readily calculated but are referred to the Machines Turnover Ratio spreadsheet.

WITNESS input
The simulation specialists developed an additional spreadsheet to reduce the amount of data interchanged with the simulator. The data from the Workload, Execution Times and Machine Turnover Ratio spreadsheets is combined into a single spreadsheet that contains only one line per production order with all its necessary attributes.

This worksheet is not made available to the user because it does not include input values but only formulas that are necessary to prepare the information for the simulator.

Criteria specification
The management of the factory specified the following important criteria:

- Total Assembly Time: the difference between the end of the last unit and the start of the first one should be minimized.
- Buffer Blockage: the percentage of time that the buffer is blocked should be minimized so the preparation line is not blocked.
- Assembly Line Occupation: the percentage of the time that the assembly stations are occupied is to be maximized.

Besides these three main criteria, another two were included as restrictions. The proposed start and finish times of any unit should not provided a large difference with the predetermined times provided by the factory management, since a large deviation could negatively influence in the rest of the plants of the factory.

Simulation Model

Built in WITNESS, it has been developed not with the idea of a user-friendly model, but as a mathematical model that needs to be optimized. That is, the model was developed to read data from MSExcel files, to automatically change the input parameters and to output the results corresponding to the selected plan back into the spreadsheets. It is then just a black box that can be thought of as a combination of a calculator and an experimenter.

However, it must be mentioned that the verification process has been very thorough. Even hand simulations for 30 units were used to trust the results of the black-box model.

The Optimization Routine

The simulation model includes a search procedure of the appropriate production plan, that is, one that satisfies the given criteria.

There are several Simulation Optimization Methodologies (SOMs) that have been applied to the development of production plans. Among the reported combinations, genetic algorithms seems to be one good possibility (for example, Iyer and Saxena 2004, Yu and Liang 2001)

However, since the area of simulation optimization is too complex to develop universal search methodologies, a different search procedure has to be applied to any new situation. As it has already been mentioned, by including expert knowledge and production characteristics and restrictions, the search area is different for any given situation, calling for a particularized search procedure, especially in terms of the objective function (Hilgers and Boersma 2001).

Therefore, to develop the search procedure, an important amount of the time was devoted to talk with the production planners to understand their doing so it could be correctly represented in the SOM. The two main thrusts at this point were to develop good initial solutions and to provide "psychological validity" (Wager and Nichols 2003). In fact, after this step, in many situations, the first plan already fulfilled the requirements. The need is just for minor adjustments of the initial plan.

At the same time, by using production control theory, several concepts are included in the search algorithm. The more important idea is that of slackness, or difference between the available time until the due date and the total production time. Those units with small slack should be scheduled reasonably soon so the due date is met.

The total production time is also a key factor. If a unit with a large production time is scheduled first, the more blockages will be produced, but the higher the line occupation and the smaller the total assembly time.

The combination then of the plant production planners knowledge with the simulation specialists input in terms of simulation and production control theory provides a search algorithm that tests a satisficing initial solution and then modifies it in an additional small set of tries.

Output Files and Worksheets

They are just raw data tables with a consensus format for the in-house software developers to produce the daily output.

Machine Utilization
For each of the stations, its utilization rate is broken into the time that it has been working, the idle time, the time it has been blocked because the next station is full and the waiting time for labor to appear to perform the necessary operation.

It is worth mentioning at this point that two are the key statistics included in this worksheet. The first one is the blockage time for the buffer or the station, which is the link between the preparation line and the two assembly lines. The buffer acts as a distributor of workload between each of the assembly lines. This block time has been included as one of the main criteria of the study, trying to be minimized.

In fact, the management main policy is that all the stations are occupied. It is more important that the plant looks fully loaded with sandwiches even if many of the stations are blocked. The second key number in the table is therefore the idle time of each station.

A good production plan is perceived then if the idle time of the stations is low and so is the blockage rate of the distribution buffer.

Gantt Chart
One of the spreadsheet is devoted to a Gantt chart that includes the unit number that should be in each station for the whole simulated period, usually a week, in intervals of one hour. This is the main control tool that the production controllers will use in a daily basis once the plan is finally decided.

Bill of materials
Another key worksheet is the one that shows the materials required at each of the entry points of the system. It is used both by the production controllers and by the other plants in the factory that supply parts to this individual plant.

The worksheet shows four lists: the first for the first station, one more for the start of Preparation B and two more for each of the assembly lines entry points.

Operation Times
For verification purposes, a table that shows the start and finish time of each sandwich at each station is created. The difference between the start at one station and the end at the previous one is then calculated to be the blockage time, which will help detect important assignable causes of blockage.

It also shows the start and finish of the whole unit so it can be compared with the planning times, which are provided by the production department of the whole factory.

CONCLUSION

An application of simulation in the ship building industry is presented. Moreover, a decision support system based on a simulation model has been developed to come up with both weekly and long-term assembly plans. The DSS has been implemented at one of the assembly plants of a huge ship building factory that will keep on developing decision support systems for the rest of the plants.

The developed DSS is a mixture of spreadsheets and a simulation model where the worksheets act as the interface between the factory database and the model. In fact, the success of the project has come not only by the art of the simulation specialists to represent the system in hand, but, more importantly, by the ability to bring the knowledge and expertise of all the people involved in the decision system into a common set of spreadsheet files. Once a consensus has been reached on the format of both the input and output files, each knowledge group is responsible for either inputting data into the common files or reading from them. Each group is to maintain also its own part of the system.

A simulation optimization methodology has been incorporated at the same time into the DSS. Searching for a satisficing solution has been achieved by first including the knowledge of the weekly programmers and the engineers into the development of a good initial solution, which is improved using sound production control theoretical techniques.

The applications software is then for planners to use, but it has been the result of a combined effort of management and developers, which have conveniently defined a set of files to interchange information, in order to represent the expert knowledge in a simulation –based DSS.

In that sense, it is worth mentioning as the final conclusion that maybe more simulation studies could be performed if the experimentation and execution of the models was done from spreadsheets rather than from the model itself. Companies and users of the model many times fear that the simulation software is too complex to use so that they prefer to interact with it from a more standard tool like the MSExcel spreadsheet.

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