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Modelling and Simulation of a Manufacturing Line in an Automotive Components Plant

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ABSTRACT

The aim of this research is the modelling and simulation of an Integrated Manufacturing Line which produces the third idle gear to be assembled in the final product, an automotive speed gear box. The manager of the plant wanted to know the maximum capacity of the line and to make some process improvements leading to a better behaviour of the system. The models constructed using System Dynamics, in a discrete line, has been validated and is been sucesfully applied to the plant. (A previous simulation study was conducted using an interactive discrete simulation software)

Keywords: Production Planning and Control Systems, Modelling, Simulation, Assembly Line, Pull Systems, Industrial Applications of System Dynamics

1. The Manufacturing Line and the Factory.

The plant manufactures gear boxes with an average throughput of 3.000 units/day. One of the items or components to be assembled into the gear box is the 3rd idle gear. There are two types of idle gear and both of them are obtained from the same raw material.

This particular component is manufactured in a Integrated Manufacturing Flow Line. The machines of the line are linked through different devices in order to handle and transport the work in process. The incoming parts fed into the line are the raw ones and the outcoming, that is the manufactured gear, goes to the next process which is the heat treatment. A view of the entire production process can be seen in figure 1.

The materials flow between this manufacturing line and the rest of the process are managed using Kanban cards in the usual way established (Spearman et al,1990; Framinan and Ruiz-Usano, 2000, 2001 and Berkley and Kiran, 1991) resembling a CONWIP control system. There are a Kanban Accumulating and a Kanban Release Boards at the beginning of the line. When the number of cards in the Accumulating Board reaches certain level these cards go to the Release Board becoming a production order entering the first machine of the line. The card is attached to the production order until the end of the assembly process, which is carried out in the assembly line. Then the card is returned to the beginning of the Manufacturing Line and goes to the Kanban Accumulating Board.

The data are as follow:

- The layout of the line.
- The machines and linking devices.
- The manufacturing process time/machine.
- Number of operators in the line
- Three shifts/day.
- Eight hours/shift.
- Weekly period: Monday-Friday
- Fifteen minutes break/shift
- Overtime not allowed.

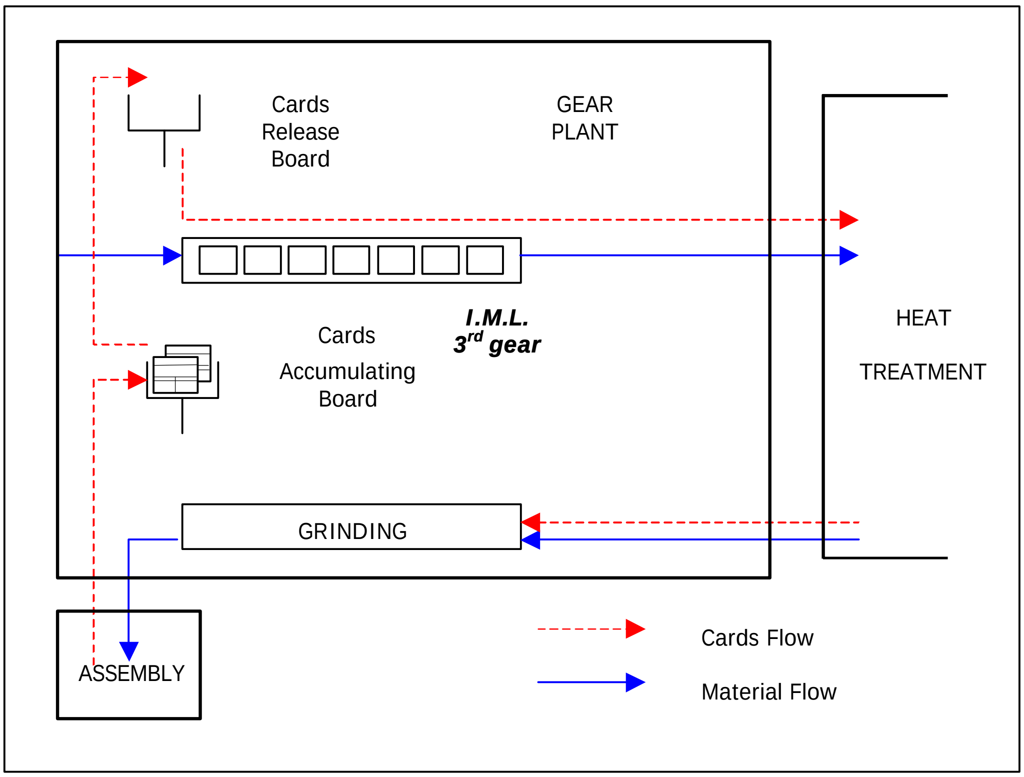

Figure 1. Information and Material Flows in the Plant.

2. The Integrated Manufacturing Line. *(I.M.L.)*

The Flow Chart of the Line is depicted in figure 2 where can be seen the operations made to the material flowing through the line from the entering raw material until the final operation of the line going to heat treatment. All the machines in the line are linked by some kind of handling device (conveyor, elevator, buffer,..). The transfer lot size is one unit. Antiblocking systems exist between the stations.

The conditions required for a machine manufactures a piece are:

- It should be at least 1 piece in the incoming handling device.
- The output handling mechanism should not be blocked or saturated.
- The machine is not out of order (no breakdows or sheduled shutdown)

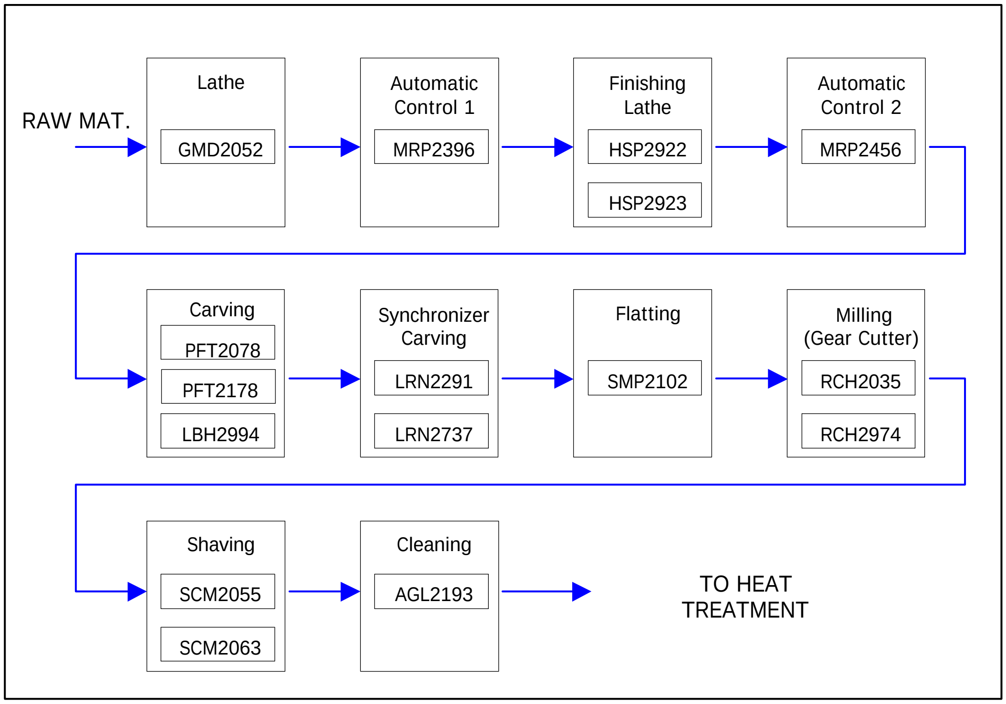

Figure 2. Flow Chart of the Integrated Manufacturing Line.

3. The System Dynamics Models.

The System Dynamics Models constructed are four:

- *Model A.* To obtain an upper bound of the capacity of the line. Scheduled shutdowns and small breakdowns are not considered.
- *Model B.* Scheduled shutdowns of the line are considered.
- *Model C.* Scheduled shutdowns and small breakdowns are included.
- *Model D.* All types of breakdowns and scheduled shutdowns are included. For serious breakdowns the staff of Maintenance Department is required.

The Scenarios to be considered are:

- No problem with the raw material supply to the line nor the picking out of the finished gear neither.
- No scraps due to quality defects.
- Change of type is not included. No setup.
- The handling mechanisms are modelled as queue tranporters in which the parts are moving at constant speed.
- No priority rules for picking the parts when there are two material flows are joining.
- No priority rules when the material flow splits.

- Scheduled shutdown is modelled as setup.
- Deterministic sheduled shutdown time.
- Maintenance Department staff always available.

The data given by the Industrial Engineering Department of the Factory have been:

- The process unit time for every machine of the line.
- Transportation time, lenght and capacity of the handling devices.
- Causes, frequency, time and operator for the scheduled shutdowns
- Fails, probability distribution (usually a negative exponential), time and operator for the shutdowns of the lines caused by small and serious breakdowns.
- Labour force in the line (usually two operators)

A causal loop diagram of the beginning of the line are depicted in figure 3 below:

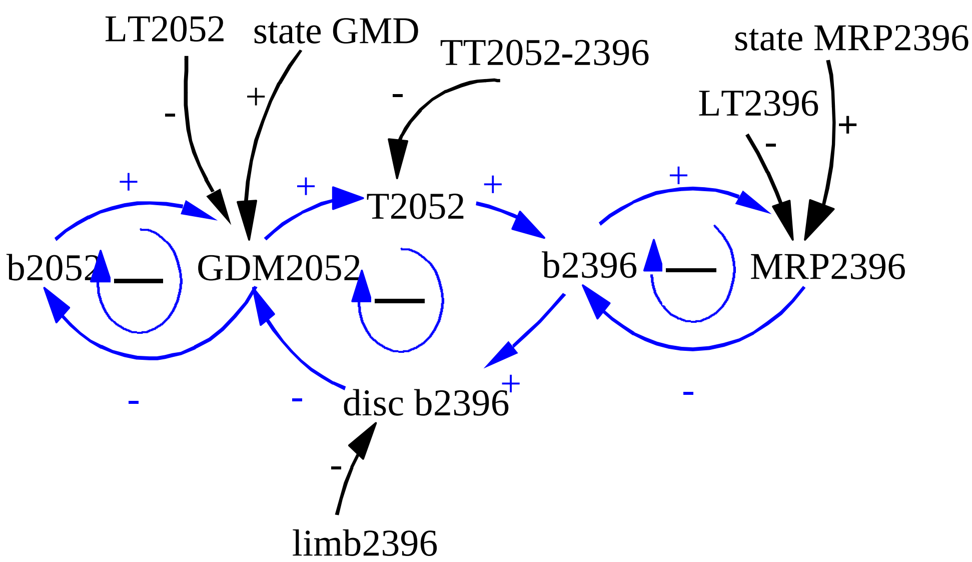

Figure 3. Causal Loop Diagram of the beginning of the line

In the figure 3 the Causal Diagram illustrates the machine GMD2052 and the transporter T2052 which feeds into the level of accumulated pieces, b2396 that go to production made in the machine MRP2396. The machine GMD2052 takes the material from the raw material, represented by the level variable b2052 and is manufactured at the pace of the lead time, that is the constant LT2052. The state of machines can take two values that denotes if the machine is working or is brokendown. The auxiliary variable disc b2396 indicates that the transporter has not reached its maximum capacity. The rate variable T2052 takes the value of GMD2052 and delays this value due to the transportation time needed between the machines GMD2052 and MRP2396. This diagram is the same for the next machines of the line. It can be considered as an archetype (P. Senge, 1990).

4. **Simulation Results.**

The different System Dynamics models constructed have been validated using the results obtained from the previous Witness model. Taking into account the discrete nature of the production process we could ask ourselves if the System Dynamics models constructed are worthwhile. The results obtained from those models have provided to the manager a better knowledge of those aspects such as dynamic behaviour, feedback loops, and how the structure of the system, i.e. the layout, ..., influences the behaviour of the line. In such way the manager can achieve a better understanding of the system and therefore to improve the efficiency of the manufacturing line.

The model have been run taking the following initial values:

- Horizon Time run: 25 days.
- Value of integration step (dt): 0.5 seconds
- Initial level values: 0

The results, of the simulation of the different models, that show the daily production of the Integrated Manufacturing Line are depicted in the figures 4 and 5. There is a big difference between the daily production of Model D, obtaining an average amount of 4094 for the case that includes all kind of breakdowns and schedule shutdowns of the line and the average daily production, 5207 parts, obtained by Model A, that excludes breakdowns and any shutdown of the line. So that, we can explain the influences of the breakdowns and sheduled shutdowns in the behaviour of the line, taking as measure the average daily production. Besides these results, we have also conducted a Failure Modal Analysis for every single machine as well as to identifying the bottlenecks and take the correct management action to protect them combining the Kanban/CONWIP System with a Bottleneck Control, (Goldratt, 1990).

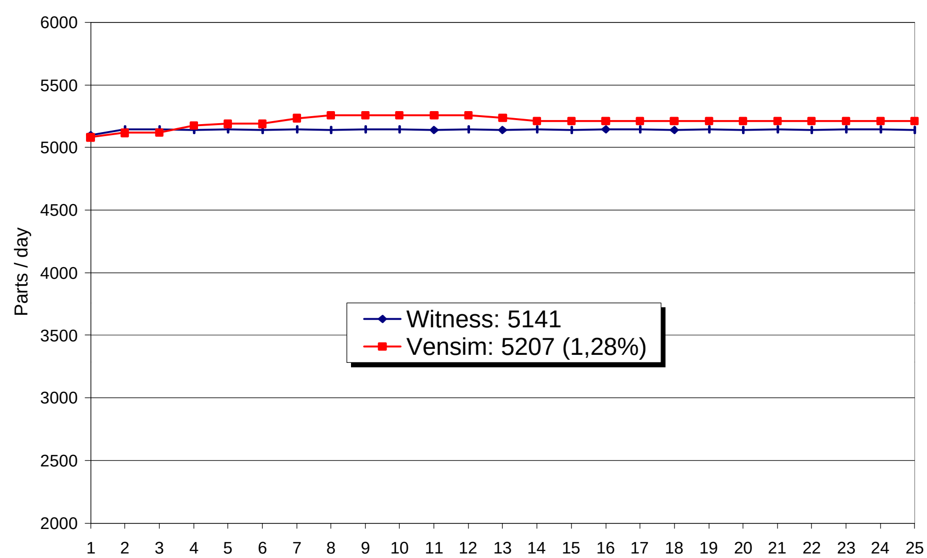

Figure 4. Daily Production Model A

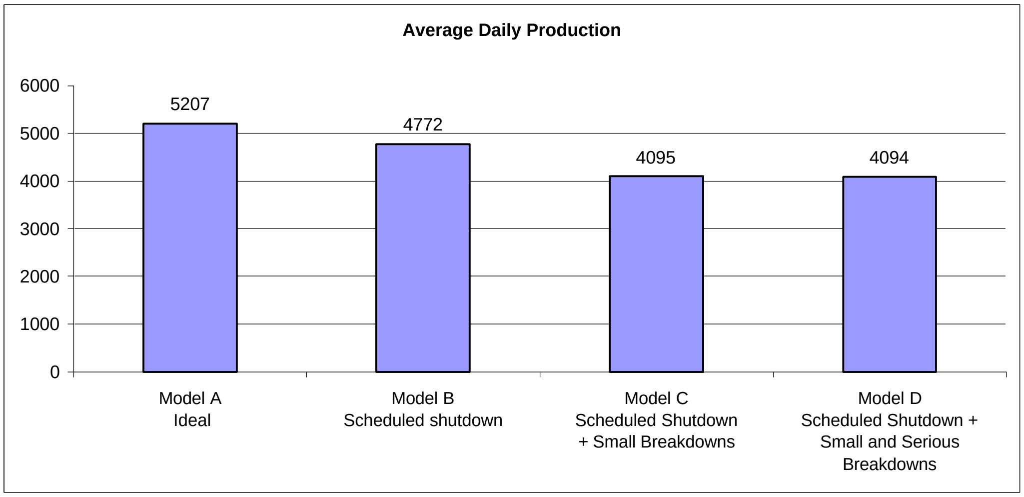

Figure 5. Average Daily Production for the Models

5. Conclusions.

We may conclude that the System Dynamics Methodology is a powerful tool for the modelling of production process, in spite of the discrete behaviour of this type of process. The results obtaining from this approach provides the managers a better understanding and knowledge of the system, particularly the dynamics, the structure and its influence in the behaviour as well as the control of the feedback loops. The true bottleneck of the line is the machine GDM2052, it is a lathe and the reasons why are:

- The higher frequency and duration of the scheduled shutdown in this machine.
- Although the average process time of this machine is rather similar to the rest, this machine is dedicated to an specific operation and there is not any more machine in the line that can make the same.

Any decision made to increase the througput of the line must protect the working conditions of this bottleneck machine. Among them: the assignment of the operator to this machine or that the priority of the functions of the 1st operator would be to manage the undesirable effects that can occur, to increase the reability of the tools or the training of the operators in order to decrease the repair or fixing time. All these actions can lead to improvements which represent an significant increasing in the troughput.

6. Acknowledgements.

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