System Dynamics: Taming Expert Systems in the Business World

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Abstract

The paper reports on a new approach for the building of Decision Support Systems based on System Dynamics and Expert Systems. The power of this approach is illustrated by using it to identify problems that exist within the production processes of a manufacturing company. System Dynamics was used to simulate the production processes and build the expert system. The simulation identifies the process where the problem exists, and the Expert System suggests possible causes to the problem and the solutions required to bring production back to normal.

Stella was the System Dynamics tool used to gain a detailed understanding of the production processes and their interactions in order to build a simulation model. The influences from this simulation model were used to structure the knowledge base of an expert system. While the expert system was an essential ingredient of the Decision Support System, the actual system that was used and its features were of secondary importance.

This paper will benefit System Dynamic practitioners who are interested in:

1) simulating a process within an organisation.
2) the application of System Dynamics to solve a manufacturing problem.
3) the relationship between System Dynamics and building of Expert Systems.

4) the use of System Dynamics as a decision making/support tool in the manufacturing industry.

Introduction

The manufacturing industry has become a vastly complex world that is both unpredictable and difficult to manage. Control of production processes in this environment has become increasingly difficult. Management decisions have largely been based on "gut feeling" and "educated guesses". These traditional techniques have been largely encouraged by the lack of accurate information on the current situation within the production processes, and managements lack of detailed understanding of the manufacturing processes themselves. The decision support tools available are inadequate for identifying the problem areas, thereby impeding the ability to focus on solving the real problem(s).

The work in this paper demonstrates the capabilities of a Decision Support System to identify problems that exist in the production operation of a pacemaker manufacturing company. In this case, the most common problems included delays, process bottlenecks, material shortages and resource constraints.

Manufacturing Operations

The company is an international organisation specialising in the design and manufacture of human implantable medical devices. The company has manufacturing operations in the Asia/Pacific, North America and European regions. Research and Development is based in Sydney Australia. The company currently ranks number three position in the world market place.

The Manufacturing Plant

The plant has the capacity to produce in excess of a thousand devices per month. Because each device is for human implant, production standards are much more stringent than those normally found in the electronics industry. "Good Manufacturing Practices" are employed to satisfy regulatory authorities and ensure that a safe and reliable product is being produced. The devices pass through several cleaning and testing stages to ensure a contaminant free, high quality product.

Decision Support Systems in Manufacturing

There are many implementations of Decision Support Systems in industry today, and each one is unique in its own right. There are Executive Information Systems, Simulation Systems and Expert Systems, to name just a few, that attempt to provide the basis for more informed decision making.

Executive Information Systems translate real data, obtained from organisational operations, to a graphical form for analysis. The result, is merely a snapshot of a constantly changing situation. The picture conveyed, based on static data, seldom provides a suitable basis for making meaningful projections into the future. This is because the projection has been made on the basis of static and historical data, rather than the dynamic forces at work.

Simulation has been widely accepted by the manufacturing industry for optimising existing operations. Simulation allows the application of what-if scenarios to visualise and assess the impact of possible alternatives. However unforseen events that subsequently arise during normal operation, that were not included in the scenario analysis, are resolved by the traditional methods mentioned earlier.

Current implementations of Expert Systems rely on the accuracy of the input provided by the experts in the field to build a knowledge base that can be directed towards solving problems. Expert Systems generally undergo many iterations of testing until the results demonstrate a high degree of correlation between the recommendations of the expert system and that of the experts. This process can be indefinite and the knowledge base may contain unnecessary, redundant or insufficient knowledge. The problem is that there is no precise way of building the exact knowledge base that is required to solve the problem.

This paper postulates an approach for building an exact knowledge base that is required to address any problem.

Performance Decision System

The Decision Support System built was based upon using System Dynamics to obtain a sound understanding of the processes in which a problem could occur. A Stella simulation was then used to determine the location and the magnitude of the problems. Once the processes were understood and the simulation was validated, the causes of the problem(s) became apparent and could be captured in a knowledge base of possible solutions. This knowledge base was then used to recommend the appropriate solution when the same or related problems occurred in the future.

Why Stella

Stella is a computer software implementation of System Dynamics principle that can be used to simulate processes. Stella is a powerful computer tool that can be used to model organisational behaviour, by capturing the influences that can lead to the disruption of a steady state system. Stella was found to be suitable for achieving understanding of the production processes. The ease of use and the graphical interface allows the user to focus on modelling the problem rather than mastering the mechanics of the program.

Model of the Manufacturing Plant

The simulation comprised of a Main Model and several Sub-models. The Main Model (refer Figure 1) is a high level view that represents the manufacturing operation with sufficient detail to identify the main processes. The Main Model explodes out to the sub-models that detail the influences affecting each process.

The sub-model includes the resources that are required by each process. The effectiveness with which these resources are balanced determines the performance of the manufacturing operation. The sub-models were developed with the aid of an expert who was responsible for the manufacturing operation. The aim of the sub-models was to duplicate the same rules that the expert used to allocate resources towards achievement of daily production targets (refer Figure 2). The manufacturing plant was simulated using typical plant disturbance data to establish that the model was capable of giving a true reflection of plant performance (refer figure 3).

The Expert System

When an expert system is being built, there is seldom an understanding of the processes and the decisions that are involved. So the classical approach is to elicit this knowledge from an expert and to reproduce the same knowledge in the knowledge base of an expert system.

This knowledge base is often found to be made of adhoc rules and rule hierarchies. The adhoc rules can represent unnecessary and redundant knowledge, whereas the rule hierarchies represent the cause-effect relationships. It is a Systems Dynamics model which can provide the framework for the discovery of these rule hierarchies. After all a System Dynamics model is nothing more than a hierarchy of influences and cause-effect relationships.

It is the mapping of the hierarchy of influences to the hierarchy of expert rules that provided the foundation upon which the Performance Decision System was built.

Conclusion

Based on the work carried out and the results obtained, it was demonstrated that a System Dynamics approach can be used to:

•understand and simulate manufacturing processes

•solve a manufacturing problem

•establish the relationship between System Dynamics and building of Expert Systems

•build an expert system based decision support tool.

The most significant aspect of this work was establishment of the equivalence between the hierarchy of influences in a System Dynamics model to the rule hierarchy contained in the knowledge base of an expert system.

Figure 1. The Main Model

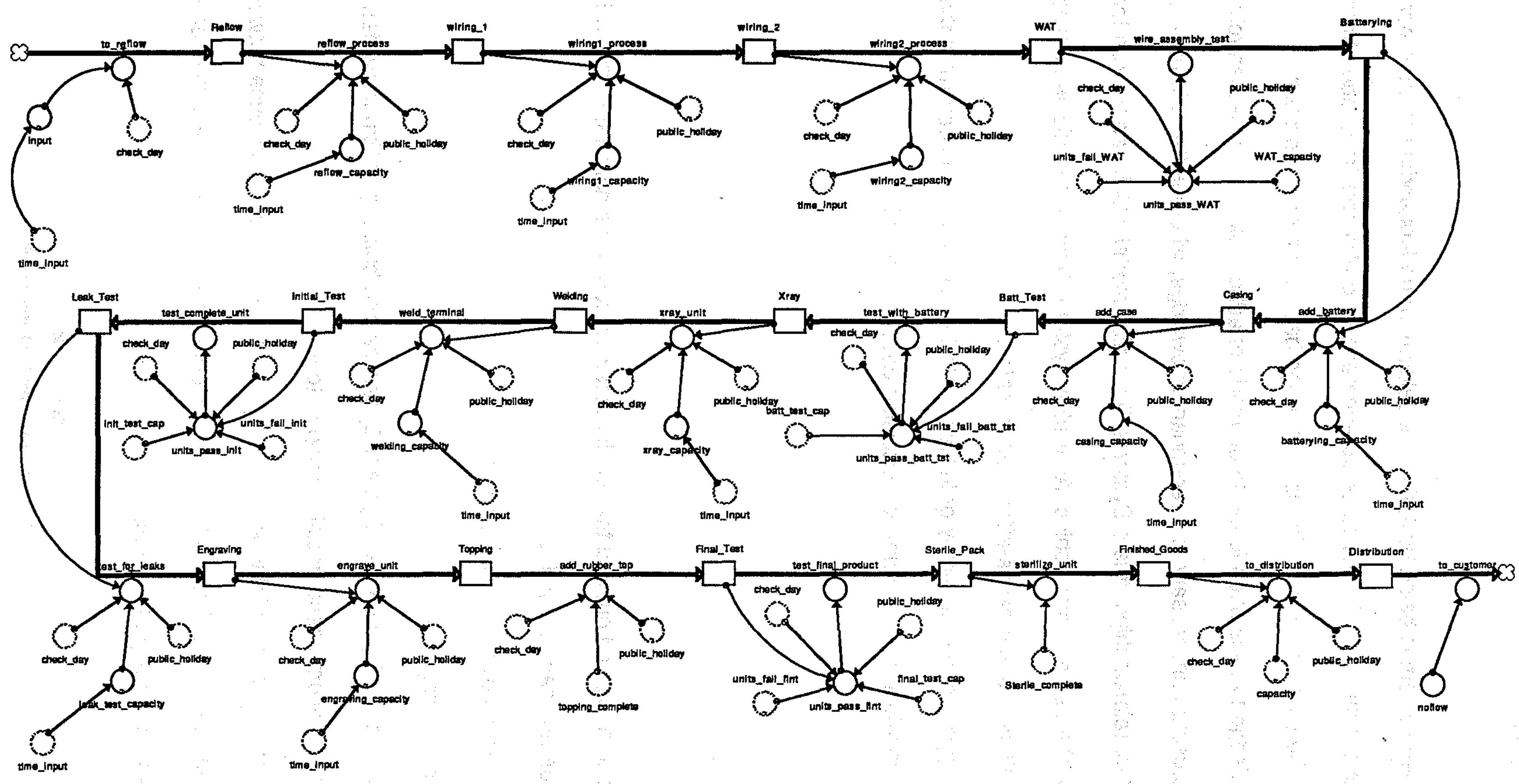


Figure 2. The Sub-Model

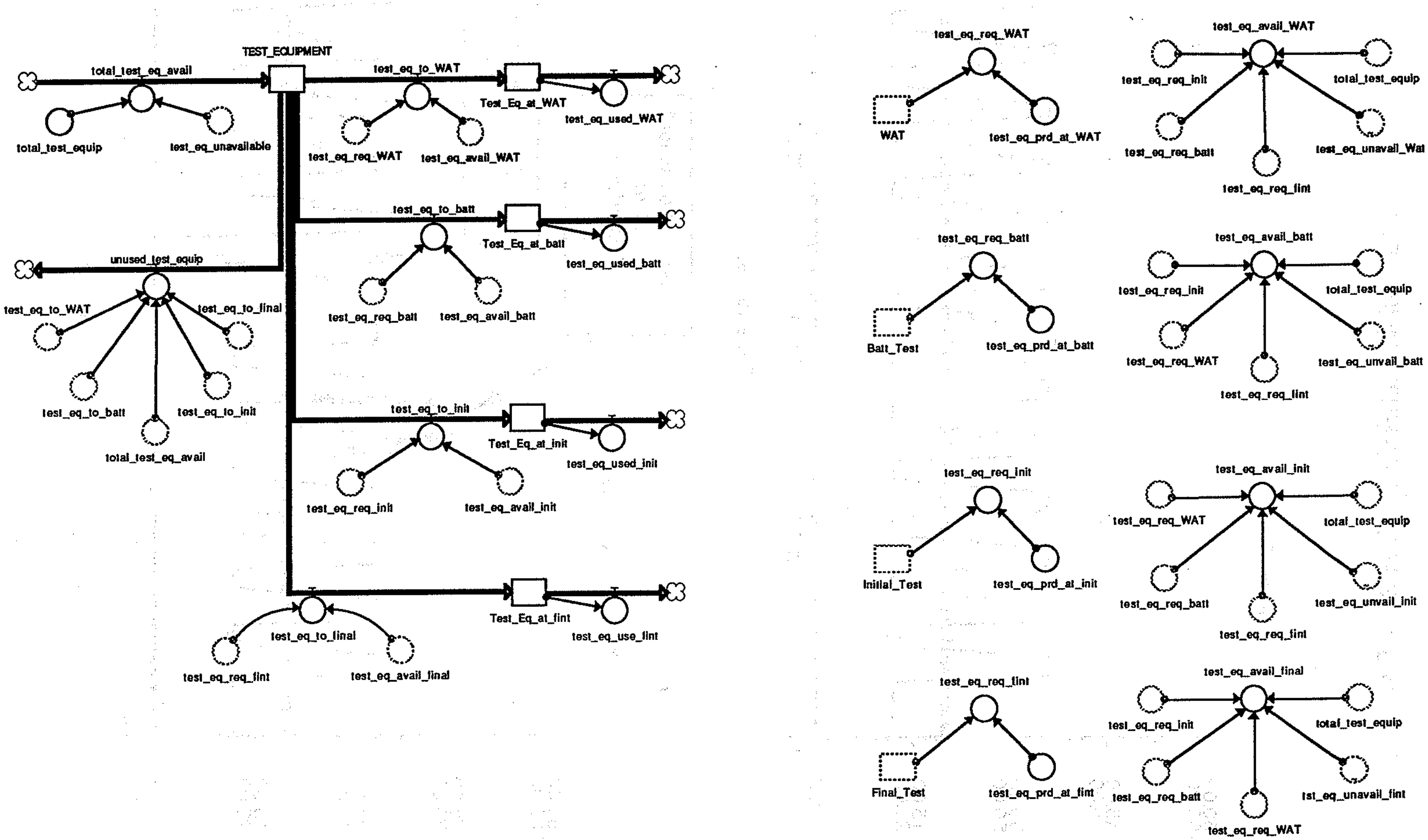
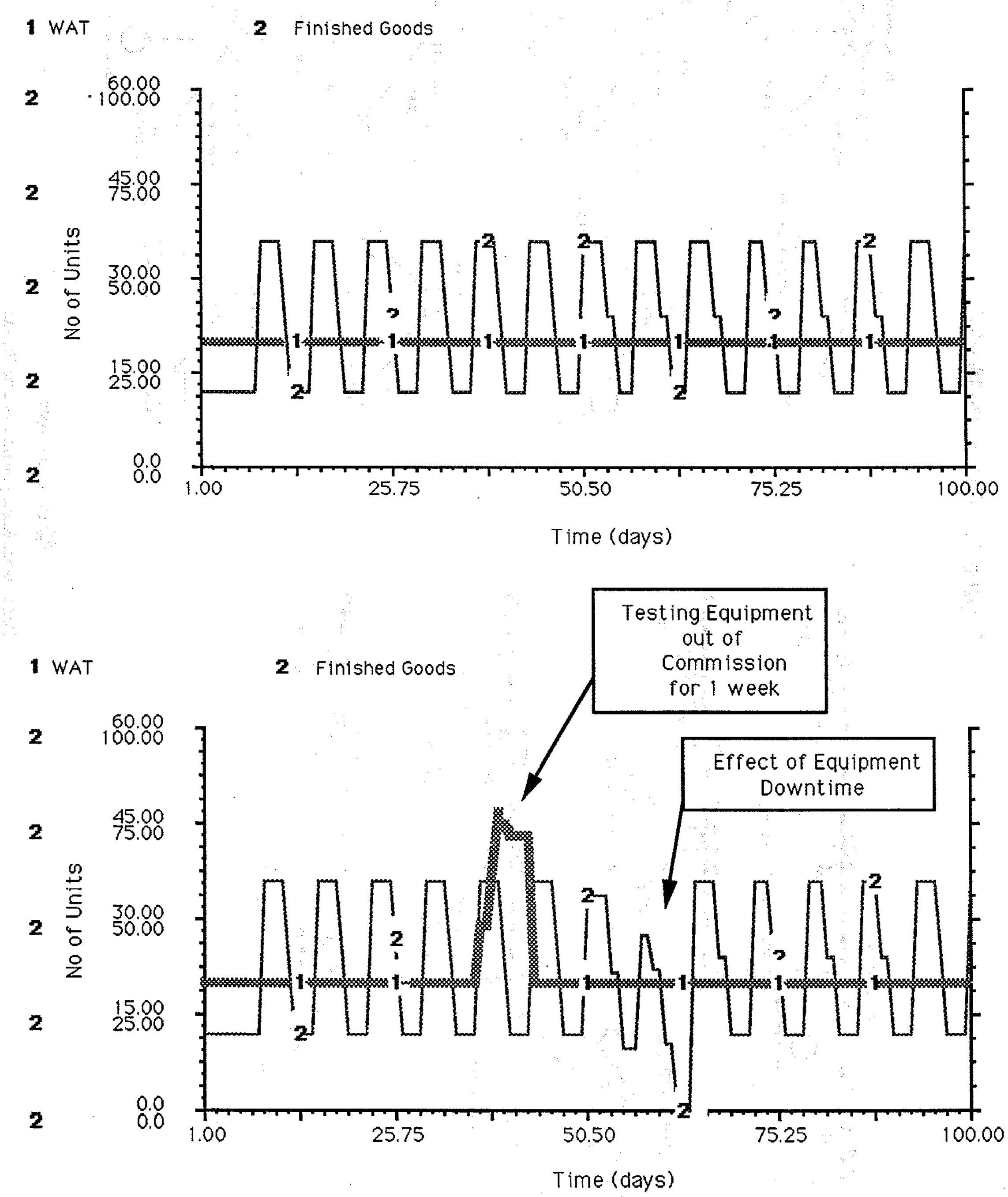


Figure 3. EFFECT OF TEST EQUIPMENT



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