Performance Decision System: An Intelligent Approach to Decision Support Systems in Manufacturing

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Abstract

Decision Support Systems (DSS) are commonly used in the manufacturing industry to assist management in decision making processes. There are several major types of DSS systems and each is useful for solving specific manufacturing problems. The development of intelligent DSS systems that can carry out high level reasoning is itself a challenge and a requirement by modern management. This paper illustrates the formulation of a DSS system (called Performance Decision System) that can be used for solving complex manufacturing problems. The DSS system is based on two major types of DSS systems; System Dynamics and Expert Systems.

1.0 Introduction

DSS systems play a major role in complex manufacturing systems. They provide the necessary support that management require for effective decision making processes. The type of information generated by DSS systems can be in the form of a) historical trends, b) projected forecasts based on trends and c) identifying causes to a problem in a production line. The type of DSS systems that are used to implement these are Information Systems (IS), Simulation Systems and Expert Systems respectively. Although each type of DSS system has its own merits for specific applications, there is no single DSS system that can solve any type of manufacturing problem.

This paper describes the development of a DSS system that utilises both Simulation Systems (System Dynamics) and Expert Systems to analyse the problem at hand. The use of System Dynamics as a method for building Expert Systems is illustrated. The DSS system was trialed on a pacemaker manufacturing system and it's performance assessed on the results of the trials. The outcome of the assessment indicated that the dual use of System Dynamics and Expert Systems gave a more global and "birds eye view" for the problem solving process.

2.0 Overview of DSS Systems Used

Although each variation of DSS systems has a characteristic that is unique for specific applications, a combination of these variations can provide the broader scope necessary to solve any problem that can occur in a manufacturing system. The combination included System Dynamics for identifying the area of the manufacturing system causing difficulty, and the Expert System to identify the cause of the problem and recommend remedial actions. The new DSS system is called Performance Decision System (PDS).

2.1 Expert Systems

An Expert System has a wide base of knowledge in a restricted domain, and uses complex inferential reasoning to perform tasks which a human expert could do (Hart 1986). Figure 1 shows the basic elements of an Expert System. The basic idea of building an expert system is to transfer knowledge from the human expert to the machine. Current implementations of Expert Systems rely on the accuracy of the knowledge provided by experts. Typically, an Expert System would undergo many iterations of testing and knowledge elicitation until the results showed a concurrence between the recommendations of the expert system to that of the experts. The effectiveness of the Expert System is dependent on the complexity of the domain, the experts knowledge of the domain and the translation of the knowledge to effective rules by the knowledge engineer.

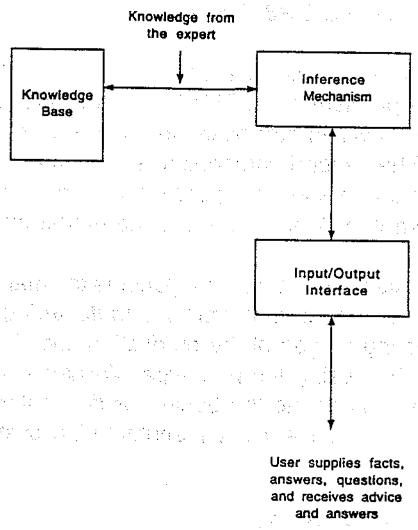

Figure 1 Basic Elements of an Expert System

2.1.1 Knowledge Elicitation

The conventional method used for knowledge elicitation is to employ the "Fact-finding by interviews" (Hart 1986) approach. This involves discussions or meetings between a knowledge engineer and the domain expert. The knowledge engineer would plan these sessions with specific objectives and questions in mind. The ultimate goal for these sessions is to obtain information about the domain in the form of rules to store in the knowledge base of the Expert System. Ideally, the interviews with the domain expert should be planned. Unfortunately, owing to the very nature of expertise, no methodology has been established for this and interviews and are likely to become ill structured, and the information gained can be inadequate and incomplete (Hart 1986).

2.2 System Dynamics

Simulation Systems have been a widely accepted method for optimising the design of a production operation for a manufacturing system. It allows managers to visualise and assess the impact of possible design alternatives (Welter 1989). System Dynamics is one type of Simulation System that utilises concepts from feedback theory for structuring knowledge about a system, and transforming this knowledge into a computer model. Models of the production operation can be built to experiment with different production layouts before committing management to plans and costs.

Simulation Systems allow one to predict what will happen in a system that is abundant with complexity (Welter 1989). However, unforeseen events that arise during production can only be resolved if the precise cause of the problem is known. Simulation Systems cannot perform complex inferential reasoning like Expert Systems, and therefore cannot provide an effective method of determining the root cause to a problem.

3.0 The PDS: An Advanced DSS System

The PDS system is composed of two major components. The first concentrates on the simulation model to identify the problem area. This involves initially identifying processes and attributes of the domain. This will in turn assist the modeller in having a better understanding of the domain. The second component is the expert system which will provide the probable causes of problems and suggests possible corrective action. The results obtained from the expert system can be fed back into the model for evaluation.

A prototype of the new DSS system was built for a pacemaker manufacturing system, to determine the validity of the DSS System in a typical manufacturing environment. The prototype was based on the testing stages of the production line. The performance of PDS system was assessed by validation using the prototype. Validation was carried out by simulating holdup scenarios and comparing the behaviour delineated by the DSS system against that which is observed in the pacemaker manufacturing system.

3.1 The System Dynamics Model

The model of the manufacturing system comprised two distinct levels, the main model and subsystem models. The main model is a high level view of the production line described in stages (see Figure 2). The subsystem models identify the attribures for each of these stages. Figure 3 shows details of a the attributes for a testing stage. These attributes are quantified by either a mathematical equation that defines the relation between the attribute and other attributes in that stage, or with an absolute value.
Both models give management a better view of different stages of the production line and the interactions between these stages. When all the attributes have been identified and properly defined, the model is complete and can be used to simulate the manufacturing system.

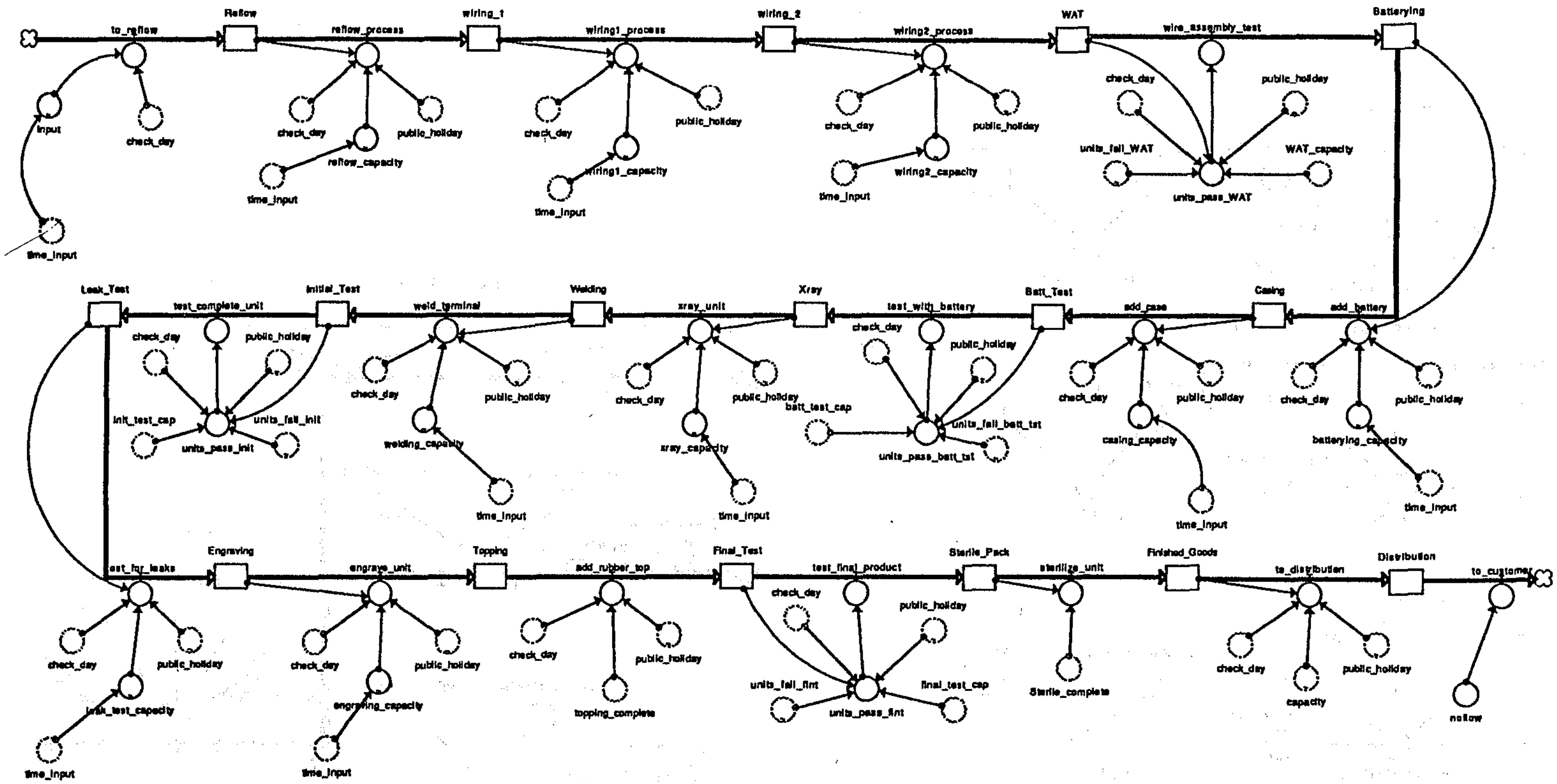

Figure 2 System Dynamics Main Model

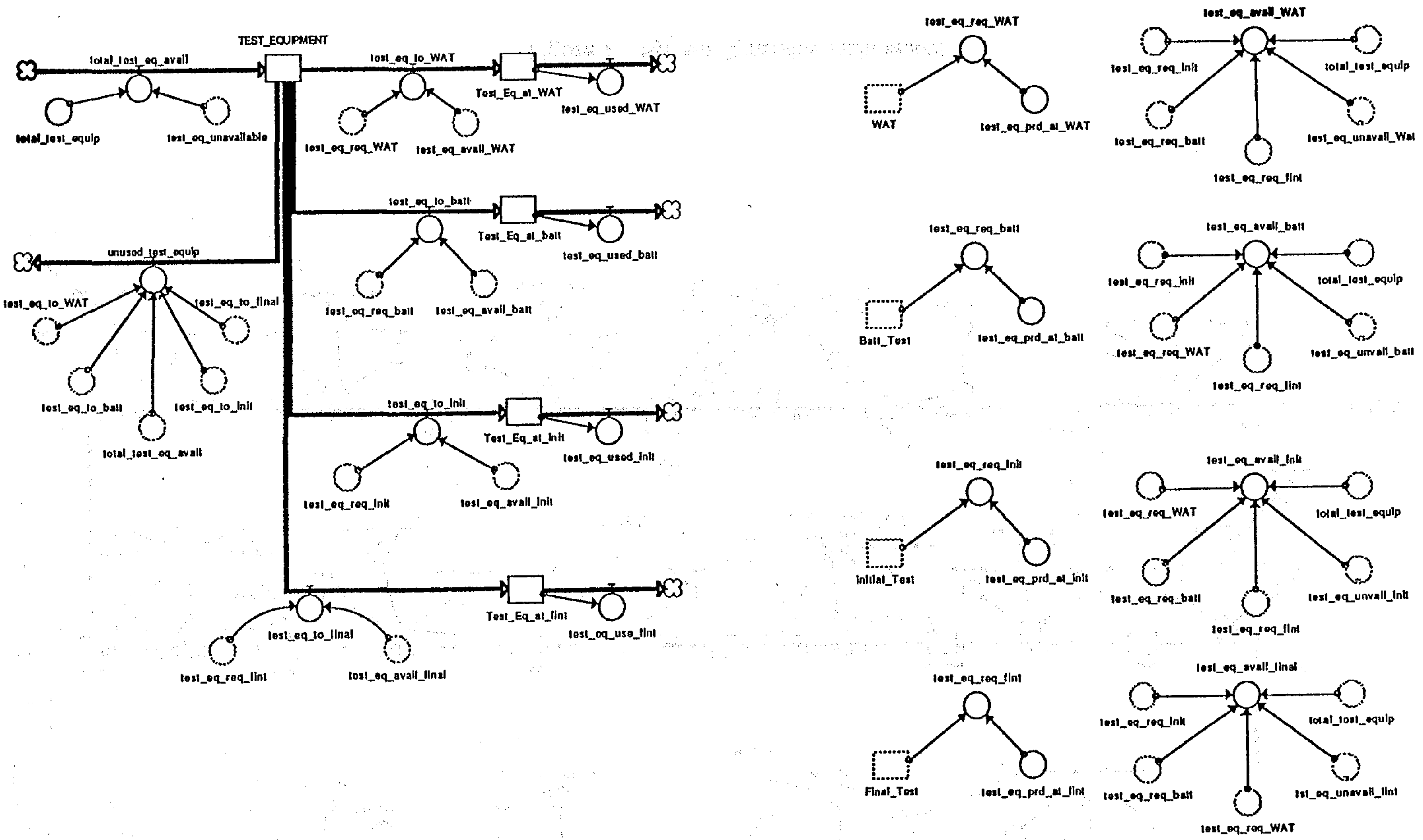

Figure 3 The Subsystem Models

3.1.1 Simulation

Production figures are reviewed on a regular basis to measure the performance of the manufacturing system against production estimates. If the productivity level has dropped without obvious cause, the System Dynamics model can be used to assist in identifying the problem area. This is achieved by applying "what-if" scenarios to each stage of the production line until the stage with the problem is identified.

The output of the simulation is shown in figure 4 and illustrates the use of the model when a problem is experienced in the production line. Figure 4 illustrates the results of a problem experienced in a testing stage and its reverberation through to the finished goods store. Test equipment malfunction is a common problem at different stages of manufacturing. It can sometimes result in extensive delays in that particular stage of manufacturing and hence production.

A system dynamics model can facilitate in forecasting future production outputs by applying "what-if" analysis to the model. Based on forecast results, shortfalls that occur during production can be prevented by selecting the most appropriate strategy over the proposed period.

3.2 The Knowledge Base for the Manufacturing Model

A sample of the knowledge base constructed for the manufacturing model is shown in table 1. The knowledge base is built on the testing stages described in the Systems Dynamics model (figure 3). Each major block in the listing contains rules on the behaviour about that stage. These rules are fired by the inferencing engine of the expert system. The user interface is the mechanism for collecting information from the user through a series of questions. A sample of a screen form with its interface is shown in figure 5. The level at which the questioning begins is at the highest manufacturing level (figure 2). This is carried out until the problem is isolated to a single stage. After isolating the problem area to a single stage, the next step is to focus on the attributes of that stage. This is to further isolate the attributes causing the problem. When all the inputs have been processed and all possible outcomes have been analysed, the expert system displays recommendations and suggestions to solve the problem and return the manufacturing system to its nominal state. A sample of the expert system's recommendation is shown in figure 6.

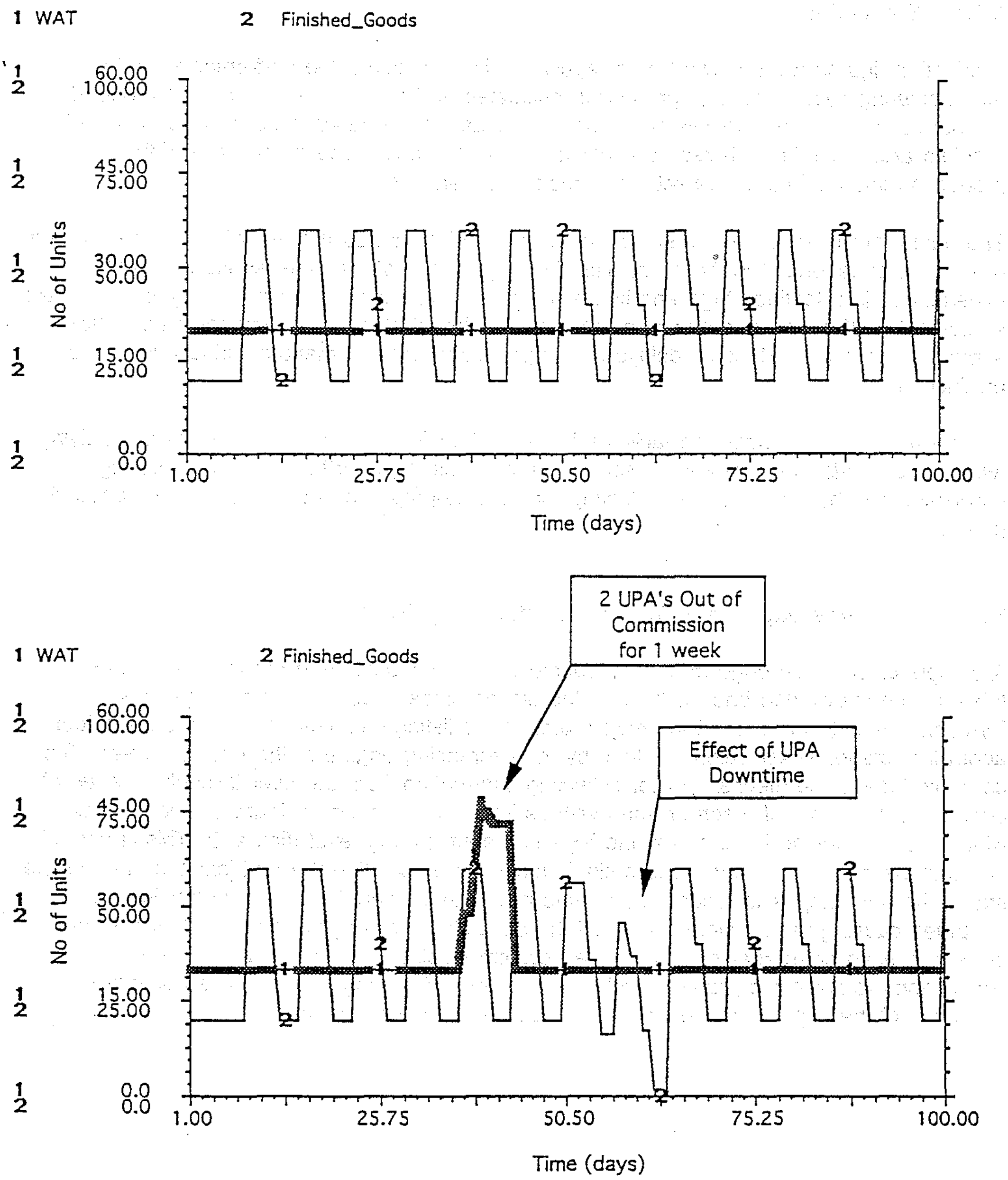

Figure 4 Effect of Test Equipment

comment

Testing Stages

```
comment   This Knowledge base contains rules that are
  and     based on the four Testing Stages of the
  and     pacemaker manufacturing.
  and
  and
  and     The Four Testing Stages are as follows:
  and
  and               – Wired Assembly Testing
  and               – Battery Testing
  and               – Initial Testing
  and               – Final Testing
```

comment *Problem with Test Equipment at Wired Assembly Testing Stage*

```
if  bottleneck is at wired assembly testing
 and wired assembly test equipment capacity is inadequate
then problem is insufficient testing equipment for the required capacity
 and do form "Wired Assembly Testing Equipment"

if  number of wired assembly test equipment < 3
 and total units at wired assembly testing > 22
then wired assembly test equipment capacity is inadequate
```

comment *Problem with Labour at Wired Assembly Testing Stage*

```
if  bottleneck is at Wired Assembly testing
 and wired assembly testing labour capacity is inadequate
then problem is insufficient man power to drive the available test equipment
 and do form "Wired Assembly Testing Labour"

if  number of human resources < 1
 and total test equipment > 1
 and total units at wired assembly testing > 1
then wired assembly testing labour capacity is inadequate
```

comment *Problem is Not at Wired Assembly Testing Stage*

```
if  bottleneck is at wired assembly testing
then problem is elsewhere
 and do form "Problem is Not at Wired Assembly Testing"
```

Table 1 Sample Listing of the Knowledge base

```
                         Application: TPSV2
                    Knowledge base: TESTING STAGES

bottleneck is ?

Select one of..

  » at wired assembly testing
    at battery testing
    at initial testing
    at final testing
    other..

Esc cancel ‖ Rtn select & proceed ‖ F3 why ‖
```

Figure 5 Sample Input to the Expert System

```
                    Application: TPSV2
              Knowledgebase: TESTING STAGES

┌Wired Assembly Testing Equipment──────────────────────────────────┐
│Recommendation: - The number of testing equipment available was inadequate for
│                  processing the pacemaker units at this stage.
│                - Check to see whether there was any maintenance done on the
│                  missing equip (total test equipment for Wired Assembly Test
│                  is 3). If there was maintenance carried out, make sure that
│                  the stage is fully equipped for the next shift.
│                - Check for equipment calibration. Uncalibrated equipment
│                  should be addressed promptly by maintenance staff.
│                - Check the condition of equipment (eg loose/broken wires,
│                  connections,...).
│                - Check that units are fitted correctly in test card.
│                - Check for correct equipment for the unit.
│                - Check that the program disk is correct.
│
│   Suggestions: Because the productivity level at Wired Assembly Testing
│                was low for that day, you must increase your resources
│                appropriately for every stage to move the build up units
│                into Finished Goods on time. Re-run the Stella model using
│                the What-if analysis to determine resource requirements at
│                each of the production stages (after WAT) for each day.
└──────────────────────────────────────────────────────────────────┘

Esc cancel║Ctrl+Rtn end║F3 why║
```

Figure 6 Sample Output from the Expert System

3.3 The Performance of PDS System

The performance of the PDS system was assessed by validation using the prototype. The PDS system was not built for the total manufacturing system. However, testing stages were sufficient to allow assessment of PDS system as a new DSS system. The simulation graphs shown in figure 4 identify stages where a problem was simulated. The output of the expert system shown in figure 6 provided suggestions and recommendations for the simulated problem.

Results of validation demonstrated the validity of PDS system as a new DSS system. The two components of PDS System were tested independently. The System Dynamics model showed the effects of a problem at a single stage of the production line; while the expert system provided recommendations on the causes to the problem and suggested solutions to bring the production line back to its nominal state.

4.0 Conclusions

The PDS system proposed and tested in this paper has provided a new approach in Decision Support System for manufacturing operations. This novel approach utilises the characteristics of both expert systems and system dynamics. A prototype of the PDS system proposed was built for a manufacturing system. The performance of PDS system for a simulated problem was assessed by validation and demonstrated close correlation with human expert assessments and recommendations.

The proposed PDS system has therefore shown to be an effective tool for assisting management in multidimensional decision making processes in a manufacturing environment. Although PDS was validated for manufacturing systems, more work is needed to investigate its applicability in other managerial environments, e.g. finance etc.

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