Design of Decision Support Systems for Extended Enterprise

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Abstract: In order to cope with market constraints, firms have to implement new management tools and maintain their organisations as efficient as possible. Data integrity and availability in this challenge becomes a success key and Decision Support Systems provide an appropriate tool to deal with these requirements. This article proposes an approach to design a relevant Decision Support System based on enterprise modelling techniques.

Keywords: Decision Support System, Production Management, Decision Support Panel.

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1. Introduction

Recent evolutions of information technologies give rise to efficient new tools that deeply modify the global management context. Nowadays, one of the most important success keys of firms is the way by which they master, store, treat and provide data. This problem has already some technical solutions such as powerful Data Bases. Nevertheless, even if a part of this crucial problem could be solved thanks to those tools, when various decision makers (from top managers till people in charge of workshops and operators) have to use the most relevant, stored or calculated, data at the right time under the most appropriate format, they are often disappointed. This is related to data structure and mapping. In fact, even if data could be stored and manipulated thanks to Data Base management systems, they should be linked to decision making situations and decision makers. This means that data has to be put in the right management context.

New information technologies, especially through the growth of Internet, make the situation more complex by bringing new factors such as multi-enterprises inter-dependencies. The use of *Decision Support System (DSS)* helps managers to cope with this situation but, the main problem is to design a DSS relevant to these operating constraints.

The article proposes an approach for design of DSS, allowing analysts to conceive a system relevant to decision makers' requirements and constraints. The approach focuses on the practical aspect of a DSS which is the Decision Support Panel (DSP) and deals with the context of firms' network [4] where the basic modelling primitive is the three-party Supplier - Focal company – customer connection.

Section 2 discusses the improvements of firms' environment :

- Focal company /Customers relationships,
- Focal company /Suppliers relationships,
- Intra-Enterprise running modes.

Among all novelties, management tools are probably the most important ones due to their influence on data generation, modification and upgrade. So, the third section gives a brief description of the most popular tools used by firms : *Enterprise Resources Planning (ERP), Supply Chain Management (SCM),* and studies their influences on the running march of firms. Section 4 and 5 discuss requirements and characteristics of a relevant DSS and provides a DSS design approach based on GRAI method. a practical and well-proved enterprise modelling approach. Finally, the last section illustrates briefly the approach through an example concerning the Production Planning Function.

2. Evolution of enterprises and their environment

The evolution of industrial context is studied hereafter from three points of view.

Focal company /Customers relations

Focal company / Customers relations should be managed more and more carefully because of customers' volatility. These relations are much more complex than ever and the idea behind their management is to identify as soon as possible the right requests of clients and capture their fidelity to the provided products and services.

These relationships may be managed thanks to a *Customer Relationship Management (CRM)* –like software. A CRM solution should help enterprises to enhance their relationships with customers and to increase the effectiveness of their sales and marketing performance. This concerns the "business-to-business" or "customer-to-business" relations.

These solutions not only let customers follow the treatments of their order, but also give a highly effective instrument to managers for analysing customer wishes and so improving continuously the enterprise's services and products.

Suppliers/Focal company relations

Suppliers, in some way, could be considered as "internal" resources of the focal company. For example, in a fully integrated system (saying an extended enterprise using SCM software packages), a customer order registered in a commercial agency triggers automatically most of the purchase orders for the suppliers. Obviously, these treatments require:

- deep improvements of management principles (switching from the synchronous and generally periodic relationships to asynchronous ones), and
- the re-design of various business relationships with suppliers.

A DSS can support these requirements due to its definition and may play an important role in this context providing necessary data to decision makers whenever and wherever they need them. For example, giving the people in charge of the Production Planning, the right amount of material needs per supplier for every class *A* components.

Internal improvements

Today, the ancient production management software is being replaced by new Enterprise Resources Planning tools which should "integrate" various functions such as Production and Accounting. These tools are planned to answer the crucial requirements of industrialists: **data integrity**.

Often, these replacements oblige firms to change or re-design their Business Processes to fit to the tools' capability. In order to redesign the Business Processes one should use the Enterprise Modelling [2] approaches to guarantee the coherence of the final solution.

Two categories of IT solutions

ERP and SCM solutions are the most commonly implemented software packages in firms.

Enterprise Resource Planning, ERP

An ERP covers some of the major functions of a company such as Accounting, Finance, Production planning, Purchasing, Stock, Commercial relations, Human resource management and Technical data management [3] using centralised or de-centralised data bases. Implementation of an ERP is highly complex and time consuming and often they are not cost-effective because they do not fit with the firm's real needs. There is a lot of ERP tools on the market, specialised for all kind of firms (discrete or continuous production, SMEs, ...) and installed by integrators (in general, consulting firms) who use their own implementation methodology.

Supply Chain Management, SCM

"Integrated Supply Chain Management is a process-oriented, integrated approach to procuring, producing and delivering products and services and services to customers." [7]. A SCM could contain functions such as Warehouse management, Transportation, Manufacturing, Procurement, Order management, Suppliers, Customers, Product development too [1], [5].

ERP and SCM tools are claimed to cover a wide range of firm's functions (with possible overlaps). Therefore, they produce a huge quantity of data that must be structured and connected to decision context. This task can be done by an intelligent filter which is a DSS (Figure.1).

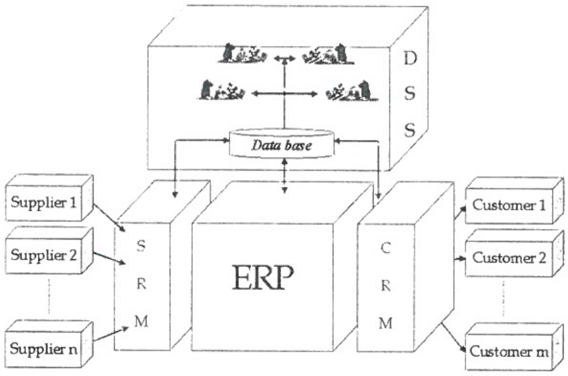

Figure 1 – DSS in an enterprise

Decision support systems

The primordial DSS mission is to structure and treat data for decision makers. Moreover, data are to be provided at the right time under the right format. The spectrum of usable methods by a DSS is very large, going from data mining techniques to neuronal networks or probability theory.

A DSS must be considered as a component of the firm's global Information System, which has to capture, structure, treat, guarantee the security and integrity of data and supply them to both control and controlled systems. The information system is then the functional interface between these two latter systems. Obviously, all data manipulated by this system do not have the same characteristics and so should not be managed in the same way.

These data can be classified as dynamic *or* static and detailed *or* global.

Dynamic or static

Some data evolve according to the dynamic of control or controlled system. For example, the resource availability or capacity $A(t)$ evolves constantly; the availability is needed for every short-time scheduling. It is important to note that a production system has a multi-level observed dynamic. It means that the real dynamic of the system is viewed or more precisely observed from various levels corresponding to various decision making levels. The capacity $A(t)$ of a workshop can be taken into account every day, week or month and this depends on managers' needs.

Others are static or supposed to be because their evolution is too slow comparatively to the system dynamic. Bill-Of-Materials and Routings are two examples of static data. Generally speaking, all manufacturing technical data can be considered as static.

Detailed or global

Some data should inform decision makers about the system global characteristics. The maximum capacity of a workshop or the backlog refers to global data.

Detailed data refer to low level pieces of information related to elements of the system. A machine capacity or the technical data of a component such as weight, colour, ... are detailed data.

This classification criterion refers to the hierarchical position of decision makers or managers (who use data) too.

Data should be available for every decision maker thanks to the DSS interactive interface called *Decision Support Panel (DSP)*. These DSPs form a complex *network* which supports an intensive data exchange and consequently allows co-operations and communications between decision makers.

To fit completely to management system and so to decision makers requirements, a DSS should be designed on the basis of a structured approach. The approach presented here is close to Enterprise Modelling approaches which look after the identification of system attributes, constraints and properties. In fact, the key idea behind the DSS design approach proposed here is : *To support decisions, one must first understand decisions makers needs.* This idea is emphasised by Power in [8] : "DS system builders need to start their analysis by identifying decision makers and the decision they need to make and not start with choosing a technology and readily available databases". So, the chosen methodology should be **decision-oriented.**

3. An approach to design a DSS for a firm

Enterprise modelling principles

Enterprise modelling approaches are basically participative and largely influenced by the *System Theory*. They focus on understanding of complex system phenomena using various models. In industrial management several modelling approaches and techniques were proposed such as CIM-OSA, GERAM and GRAI [2]. They offer both, global and detailed understanding of production systems.

Appropriate formalisms like SADT, IDEFx, GRAI (Grid and Net), or even Petri Nets, ... help analysts to model, analyse and understand deeply various functioning modes of a production system.

As the focus of a DSS is on decisions, the approach uses the GRAI model and associated formalisms (GRAI Grid and Nets) [2] in order to identify **analysis Models Base** and **design Models Base** of a decision system.

The GRAI Grid formalism is used to describe the global decisional structure of an enterprise as a set of organised Decision Levels. According to the GRAI approach, each decision level in an hierarchical control system is characterised by a couple of temporal entities (Horizon and Period) and is structured by a set of coherent and co-operative decision centres (DC). Moreover each decision centre belongs to a clearly defined function (such as production planning or purchasing). Decision centre represents the smallest logical element of the decision system. Let DC_i^v be the *i*-th DC of the v -th decision level. Each DC_i^v has its own objectives and ought to cope with decision framework sent by its superior decision centre DC_i^{v+1}.

DCs perform various activities and are highly inter-connected. These connections represent their data exchange. GRAI Net can model, as detailed as necessary, these activities and their interactions (*cf.* Appendix A1 for an example of GRAI Net). GRAI models are the basis of the decision support design.

GRAI approach like other enterprise modelling approaches uses the abstraction level concept. In fact, a system could be modelled through (at least) two abstraction levels: Logical and Organisational. The decision support design uses these abstraction levels too.

DSS logical architecture identification

It means that the functionality or activities of management system are studied, without considering any tool or resource. This identification allows analysts to determine the *informational environment of each business process (BPIE)*. In fact, the knowledge extractable from GRAI models is enough to allow analysts to do this identification from various points of view, each of them corresponding to one business process. So, the information needs of the DC_i^v is identified from integrated (GRAI) model of a several business processes.

This means that every DC_i^v could participate to more than one decision process. For example, a DC_i^v can be a member of a mid-term Production Planning process as well as a member of the quality circle. This property can be referred to multi-dimensional decision support panel. So, a BPIE is treated as a set of informational environments identified for every decision centre belonging to various business processes.

DSS operational architecture identification

The identification of the *decision makers informational environment (DMIE)* is the second phase of DSS identification. Here, not only every decision support panel must be determined, but also any communication and data exchanges between them are clearly modelled (Figure.2).

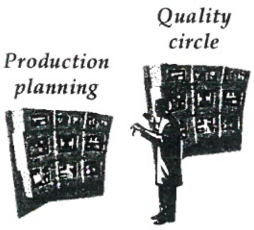

Figure.2 – Multi-dimensional decision support panels

Finally, the relevancy of each identified decision support panel is assessed from two points of view:

According to the BPIE. The proposed decision support panel should be relevant to the business process and the function (Production planning, ...) of the decision centre for which it has been designed, and should allow exchanging information with other decision centres.

According to the DMIE. The designed decision support panel has to correspond to the responsibilities of every decision maker of the decision centre and must allow co-operation and data exchange with others.

DSP design

The proposed approach consists of several phases modelled using IDEF0 formalism (*cf.* Figure.3). These phases, each of them represented by an activity, are :

- Analysis of the control and controlled systems (organisational, *#A0* and logical, *#A1*).
- Appraisal of the real situation of the firm *#A2*.
- Design new functioning models for the control and controlled systems (logical, *#A3* and organisational, *#A4*).
- Identification of the business process information environment based on the design models of the firm identified in the last phases (*#A5* and *#A6*).
- Identification of the decision maker information environment (*#A7* and *#A8*).
- Identification of the network of decision support panels (*#A9*).

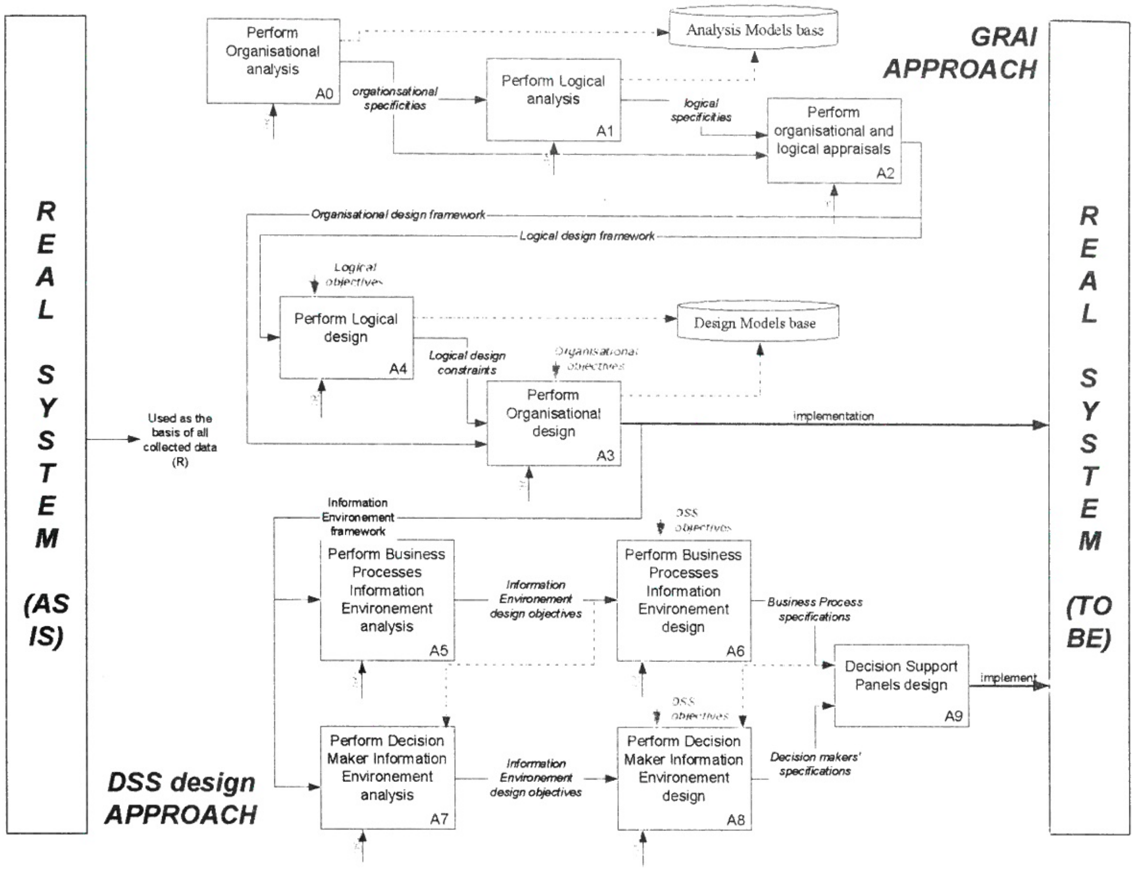

Figure.3- DSS design approach

System analysis (#*A0*, #*A1*). During this phase the decision system and the controlled system are studied first from the organisational point of view *(#A0)*. The obtained models (GRAI grids and nets) form the organisational part of the analysis models base. The second phase consists of the logical models determination *(#A1)*. The complete analysis models base should provide an exact view of the running modes of the enterprise. These past phases are performed according to the GRAI approach, thanks to managers audits, systems observations and data acquisition. It should be noted that even if these two activities are represented separately, during a real application of the approach, they are often extremely close and the models are obtained during the same audit interviews and analysis.

Appraisal (#*A2*). All of the organisational and logical models are then studied deeply using various GRAI rules and fields' expertise (such as production planning, marketing, ...) in order to identify a list of "points to improve" of the system. These points represent the symptoms of problems that a firm has to face. Once these points identified, based on strategic objectives (commercial, production, ...) of the firm a precise action plan is set up defining the firm's priorities and giving a time interval for every improvement action and providing a performance measurement protocol.

System design (#*A3*, #*A4*). These improvement actions are concretised by working teams who have to design a set of new functioning modes. The major results of these working teams are in fact the design organisational and logical models. They describe new running modes and have to be as detailed as necessary for each decision centre. Again, these models (logical and organisational) will be prepared basically using GRAI grids and nets[1].

Identification of Business Processes Information Environment (#*A5*, #*A6*). The design of logical models of the decision system and business processes allows decision support designers to determine the business process information environment for each decision centre.

1 - *Interested lectures are invited to read the article [2] for further information about these past phases.*

In fact, as detailed analysis and design models are obtained using GRAI nets, two kinds of activities are systematically distinguished: executions and decisions. These latter activities are characterised by four sets of elements, which are ***objectives***, ***decision variables***, ***constraints*** and ***criteria***. Additional data could be delivered to decision activity too. So, through a systematic study of each decision activity, decision support designers will be able to identify complementary data that must be provided to permit the most efficient execution of activities. Obviously, this identification has to be validated by managers through several meetings and discussions.

Figure.4 illustrates this situation where decision support designers determine a set of complementary data that has to be used by the activity which is "To Perform the Master Production Schedule".

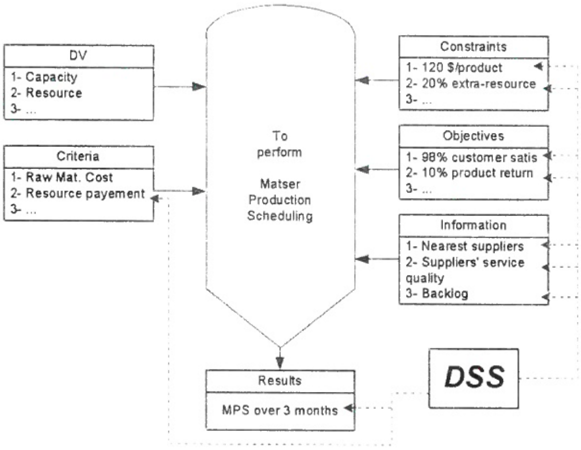

Figure.4 – DSS Supporting a decision

Identification of Decision Maker Information Environment (*#A7, #A8*). Design models of a given decision centre define the framework for the design of decision support panels for decision makers. This framework must be coherent with the roles of each decision maker.

On the other hand it is rare that just one decision maker executes the activities of a decision centre. Hence, there is no equivalence between decision centres' arborescence and those of decision makers. In this situation, according to managers' tasks and technical environment, their informational needs vary from one manager to another. So a unique BPIE of a decision centre may be transformed into as many DMIEs as decision makers.

Identification of DSPs (#A9). The final phase of this approach consists in determination of the most relevant way to represent the data required by each decision maker. This specification depends on the technology environment used in the firm and may vary from one decision support panel to another. Moreover, every decision made for the support panel has to be validated by users and in particular for its ergonomic aspects. This phase of the decision support design approach needs a very close co-operation between designers and computer science specialists.

For the existing decision support systems on the market, during this phase designers have to ensure the availability of the data format required by the final users.

DSS architecture

The DSS architecture should contain a Data Base, a specific module which can be called "dispatcher" and a network of identified decision support Panels. The database collects and provides the input data to the dispatcher who treats them and makes them relevant to the decision level of every decision maker. The resulted (or output) data are provided to decision makers thanks to the network of decision support panels.

Data dispatching in a DSS

The core element of DSS architecture is the dispatcher whose objectives are :

- to dispatch data "horizontally" between the decision centres belonging to **one decision level.**
- to dispatch data "vertically" through **various decision levels.**

Horizontal dispatching

It concerns data distribution between DCs which belong to a same level of decision making (*cf.* Figure.5). The criteria used to distinguish required data for each decision centre depend highly on the study context and cannot be examined in detail. For example, decision centres belonging to Planning, Technical or Human Resource Management functions may use the cell capacity, because they make decisions based on resource availability. On the contrary, a Quality decision centre does not use this information for its decisions.

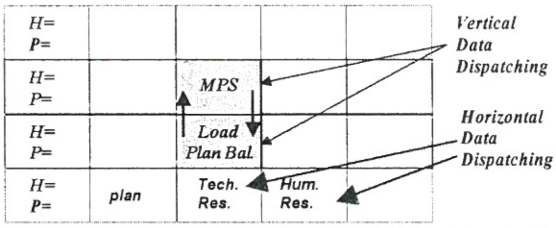

Figure.5 – Horizontal and vertical data dispatching

Vertical dispatching

It concerns data coordination between DCs that belong to different levels of decision making. Two kinds of treatments are considered :

- The **Top-Down dispatching** which concerns data disaggregation. This specific class of treatments implies the intervention of a decision process and is not studied here due to dependency on decision makers' expertise and the fact that they are rarely fully automated [6].
- The **Bottom-up dispatching** which concerns data aggregation. Data aggregation refers to complex processes as they use a very large variety of possible data and associated treatments [9], [11], [12], [10].

Example

This example concerns one decision centre called **Master Production Scheduling** in a multi-level organisation. A very detailed model of activities of this decision centre is provided in appendix *A1*. This model uses the GRAI nets formalism where a decision activity is represented as a vertical item (*i.e.* the activities *2a* and *3a*) and an execution activity is represented by horizontal item (*i.e.* the activities *1*, *2* and *3*). Moreover, this model is determined during the organisational level design which means that all decision makers and technical resources used for every (decision or execution) activity are clearly identified.

The most important decision activity in this model is "*To simulate the Production Orders allocation*" (activity *3a*) which is the one where the feasible production orders are determined and planned (*cf.* appendix A2). Like every decision activity, decision makers have to have at least the following elements : decision variables, constraints, criteria and objectives concerning the activity. The way by which these decision elements are used is out of the border of decision support design and remains under the control of decision makers and their expertise which is not analysed here. But, the final decisions should be based on various data or performance indicators. After studying the system thanks to the presented approach here, analysts suggest the use of the following data (aggregated and treated for the decision centre):

- Resource availability rate,
- Delivery delay rate for customers,
- Operator's qualification level and
- Desired quality level of final products.

3 people (two actors and one main manager) participate to this activity. The relative hierarchical position of these actors is shown in the appendix *A3*, first column. This table represents managers (rows) involving in various decision activities (columns). The relative hierarchical position of decision makers can be identified thanks to row levels : a manager belonging to a higher row is hierarchically superior to a manager belonging to a lower row. Moreover, for each decision activity, just one decision maker has the global responsibility. For, the Master Production Scheduling (the first column), the planning scheduling staff is the main decision maker while two managers in charge of workshop and critical component supplying are the decision actors (*cf.* appendix *A2* and *A3*).

Once, all these decision making rules identified, decision support analysts have to set up a decision support panel which contains at least the four previously identified data. The way by which data should be represented obviously depends not only on their nature but also on the requirements of decision makers (*cf.* appendix A4).

3. Conclusion

DSSs are key solutions for managers. The design and implementation of a DSS require a deep analysis of the actual decision environment. The approach proposed here is based on system modelling and the identification of all information needed for decision making to provide a clear understanding of real data exchanges between decision makers and consequently between DSPs. The approach is based on the GRAI approach and its main formalisms.

The feasibility of the approach depends on how deep should or could be the design of decision support system. In fact, various obstacles, such as time constraints, technical constraints related to the used information system infra-structure or the constraints related to a pre-chosen decision support system provider may reduce the feasibility of approach as a whole. Nonetheless, despite these real constraints, a relevant decision support system represents such a business strategic factor that a clear modelling of real needs guarantee benefits of implementation of a DSS , even a close-to-requirements one.

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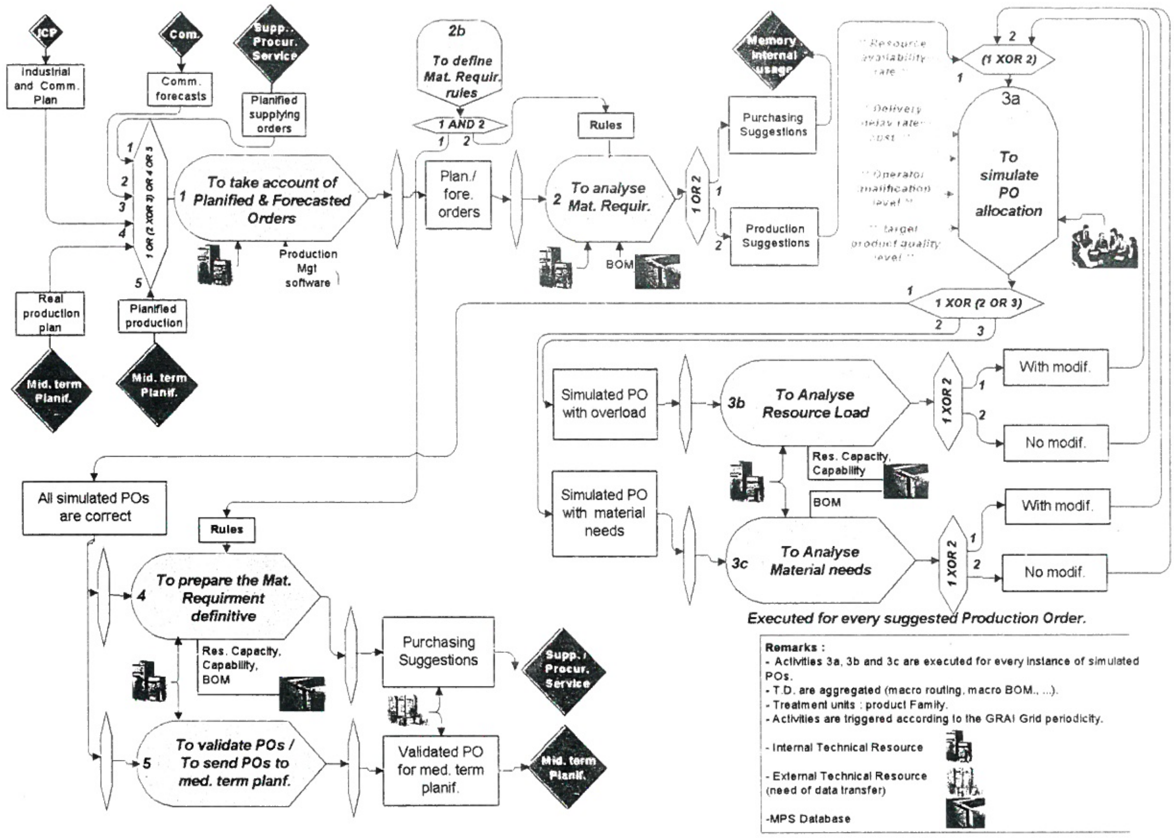
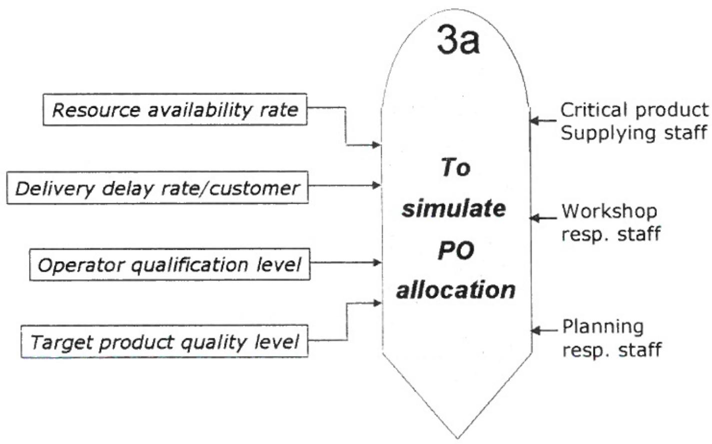


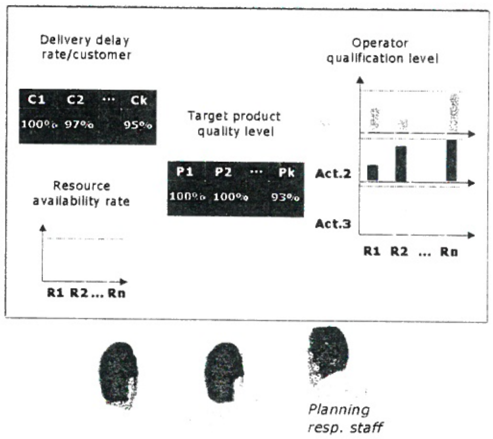
Appendix A1 - Master Production Scheduling design model (organisational level)



Appendix A2 - Transformation of a logical design model to an organisation design model for a decision activity

	MSP	To Balance Load & To Cal. Mat. Req.	To Schedule	To Launch
Critical product Supplying staff	Actor			
product Supplying staff		Actor		
Scehulder			Main Decider	Actor
Workshop resp. staff	Actor	Actor		Main Decider
Planning resp. staff	Main Decider	Main Decider	Actor	Actor

Appendix A3 - Organisational design model : role identification matrix



Appendix A4 - Decision Support Panel definition for the decision makers of the "To simulate PO allocation" activity