A rule-based support system to Make or Buy decision

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Abstract

This paper deals with the use of a software tool to support senior manufacturing managers in their Make or Buy decisions in the frame of Manufacturing strategy.

The development of this software is described, from the very first specifications elaborated within ESPRIT IMPACS' WP2 "Business Planning" to an object-oriented and rule-based PC/WINDOWS software application recently developed.

Keywords

Manufacturing strategy - Make or Buy - decision support tool.

1 INTRODUCTION

Industrial interest for a software tool able to support and document their strategic Make vs. Buy decisions as well as to keep track of the influencing factors taken into account in their past Make or Buy decisions has led LAP/GRAI to carry on a research work initiated some years ago in the frame of the IMPACS project.

In this paper, after having characterised the main elements of a Make or Buy decision, we shall describe the specification and development work performed over several years, from the first prototype in the IMPACS project to the last application developed; prominence will be given to the problems encountered as well as to the solutions brought all along this process.

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2 THE MAKE OR BUY DECISION

The Make or Buy decision has been found to be the most misunderstood, gut feel decision taken by senior manufacturing managers, especially because of traditional cost accounting techniques of contribution and overhead calculation.

Make or Buy relates to the degree of vertical integration within a business unit and to process positioning strategic choices.

The Make or Buy strategy defines the firm's boundary and the type of relationship to establish with suppliers, sub-contractors and customers ; it also aims at modifying those boundaries and relationship when required.

Part of a Company's Manufacturing Strategy, Make or Buy selects among products and/or activities those which should kept internally and those which should be sub-contracted externally.

The definition of the boundaries of an activity is based on the supply chain concept which describes the total sequence of operations from raw material extraction to product delivery to the final customer.

A firm, positionned between its suppliers and customers on its supply chain, might wish to modify (extension or reduction) the scope of its activity on the chain, in order to integrate vertically or focus on its core business.

In any case, the vertical integration strategy has to decide upon the direction (upstream or downstream) and limit of the extension ; it should also dispatch available capacities on the activities kept in-house.

To sum up, Vertical Integration decisions aim at internally balancing potentials and capacities and at externally maximise the company's manoeuvrability in front of its partners (suppliers, customers, etc.).

(Porter, 1980) provides a very useful framework for analysing the key drivers in the Make or Buy strategic decision ; he has proposed a very well known « five forces model » for depicting a competitive sector and assessing its profitability level. He considers five main explanatory factors to the profitability of an industrial sector : supplier power, customer power, rivalry among the sector's firms, risk of new entrants and danger of substitution products.

Vertical integration is grounded on the idea that ressources ownership (« make ») is the best way of keeping straight control on an activity ; as developed in the extended enterprise paradigm, alternative solutions exist, such as long-term « partenariat-type » relationship between a company and its suppliers (resp. its customers); yet even if the scope of the strategic decision has been enlarged, the influencing factors remain the same.

3 ORIGIN OF THE MOB SOFTWARE : ESPRIT 2338 « IMPACS »

The aim of the IMPACS project (Integrated Manufacturing Planning And Control Systems) was to improve industrial firms' performances through the developement of an integrated architecture and associate software support tools to manage

discrete parts manufacturing from Business Planning to Production Activity Control ; The key idea was to propose global solutions to solve a set of management problems usually considered separately.

Nine industrial and academic partners (ALCATEL (B), project leader ; TITN (F) ; CENTUNION (E) ; COMAU (I) ; DIGITAL (IRL - D) ; LAP/GRAI (F) ; PA CONSULTING (GB) ; CIMRU/UCG (IRL) ; and Laboratoire de Marcoussis (F)) have brought their experience and knowledge in software development, modelling as well as test-sites applications.

The project was split up into five workpackages covering both the managing functional hierarchy , Business Planning, MPS (Master Production Scheduling) and Factory Co-ordination, and two support areas, Architecture (modelling) and Information Technology (Software Development).

The main results reached include :

- a complete and integrated modelling of an industrial firm according to the GRAI approach : functional view, information, decision, physical models ;
- Several industrial test-sites validating the overall approach ; and
- Several computer tools developed in a Quality Assurance approach among which a Rule-based software for MPS decisions and two GDSS (Group Decision Support Systems) prototypes for the Business Planning level (capacity and Make or Buy decisions).

3.1 WP2 : “Business Planning”

The specific aim of WorkPackage 2 was “to understand, model and develop software support tools for the manufacturing strategic level”.

The IMPACS vision of Business Planning (IMPACS, 1991) is grounded on research work from (Skinner, 1985), (Hayes and Wheelwright, 1984), (Hill, 1989), as well as (Porter, 1980).

A State of the Art work has led to consider Business Planning as composed of Manufacturing Strategy formulation and Long Term Production Planning.

Manufacturing Strategy can be defined as the set of choices, visions and decisions that determine the production system structure, ressources and infrastructure in the aim of ensuring the best fit between the industrial firm and its environment ; strategic objectives formulation should be continued towards their translation into effective change projects (Garvin, 1993).

In IMPACS, Manufacturing Strategy has been splitted into six categories : Infrastructure, Human Ressources, Capacity, Process, Facilities and Make or Buy.

Capacity must be understood in its broadest sense ; it means « capacity to satisfy the customer ». Three capacity sub-types can help a company in satisfying its customers : manufacturing ressources (people, equipment, extra-hours, etc.), inventories, and cash. A capacity strategy would place each capacity decision - timing and sizing of capacity increments - in the context of a longer term sequence of such decisions.

Facilities decisions aim at defining the size, location and specialization of manufacturing entities (plants, warehouses, etc.).

Human resources policy as a Manufacturing Strategy sub-category concerns people working in the production area ; its aim is to draw up the organization and the payment systems in accordance with decisions made in other categories.

Process choice is linked to the appropriate way for an industrial company to manufacture given the market and associated production volumes involved. (Hayes and Wheelwright, 1984) define a process strategy as « *a pattern of decisions : those related to technical specialities [...], those related to operations management [...] and those related to general competitive capabilities* ».

Supporting structures, controls, procedures and other systems are collectively known as the manufacturing **infrastructure** (Hill, 1989) ; the Infrastructure sub-category consequently includes all strategic decisions that will ensure that the manufacturing system's infrastructure will be developed and built with respect to the corporate strategy objectives and will fit and support the structural choices (process, facilities, capacity) also made within the Manufacturing Strategy.

As already described, **Make or Buy** decision relates to the choice of which products and/or activities should be kept internally and which ones should be externalized. Products or even services can be concerned by Make or Buy.

Recent research works in the field of Manufacturing Strategy propose a similar decomposition into subcategories (Mills et al., 1996), (Platts et Gregory, 1992).

3.2 IMPACS GDSS prototype

WP2, with WP5 (Information Technology) has specified and developed a Group Decision Support System prototype to support the Make or Buy decision.

Based upon both consultants' and industrialists' expertise and theoretical knowledge (Porter, 1980), (Hayes et Wheelwright, 1984) and (Hill, 1989), 44 rules were found, 22 leading to a "Make" decision, 22 to a "Buy" decision.

These rules were expressed in the « IF ... THEN ... » formalism, such as :

IF *supplier power is **high***
AND *customer power is **low***
AND *internal constraints in favor of Make are **low***
AND *external constraints in favor of Make are **low***
THEN *the decision should be « **Make** »*

Yet, as any prototype, this one was not operational by the end of the project ; it needed further work, in specifications as well as in software development :

- for the decision to be made, all conditions in a rule had to be true, which is rarely the case;
- no coherence check had been made on the rule base ;
- developed on a DEC Station, with a proprietary Operating System, it needed an improved portability;
- due to the high number of facts (123), the user interface was too poor.

4 FURTHER RESEARCH ON MAKE OR BUY AT LAP/GRAI

Due to industrial interest and because of the non-operationality of the software available after IMPACS, LAP/GRAI has carried on the exploitation of IMPACS' work in the field of a Make/Buy expert system through three steps.

4.1 Coherence check of the rule-base

As already mentioned, no coherence check had been performed on the IMPACS rule-base ; (Frances, 1993) studied the IMPACS rules in order to identify coherence problems; three types of problems were found, namely (Ermine, 1990):

- *redundancy problems* (two rules triggered by the same set of facts, leading to the same conclusion),
- *conflict problems* (two rules leading to contradictory conclusions), and
- *looping problems* (rules inferring without end).

The structure of the rules as resulting from Frances's work remain very simple : they formed a tree whose leaves were the initial facts and whose root was the final choice : make or buy ; yet, for taking future enrichments into account (adding rules and/or facts), the principle of an expert system has been maintained.

Moreover, Frances has brought the idea of using an object-oriented database to store the values of the facts.

4.2 New specification book and validation through simulation

Based on (Frances, 1993), (Vidalie, 1994) has carried on the specification work.

His research work has allowed to get :

- a clear and complete specification book;
- new concepts in order to take into account the fuzziness and uncertainty of information in strategic decisions (Jackson et Browne, 1992) : Certainty Factors (probability of the fact), Ponderation Factors (weight of the fact in the rule) and calculation formulae to deduce facts values from initial facts values, by propagation in the rules tree;
- a validation of the approach through simulation (by using Systems Dynamics).

This research work has clarified a lot which functionalities the software tool should fulfil and has given evidence of its applicability on a case study.

4.3 MoB, operational decision support tool

The third step in the development process has been performed by (Davrou et Lefelle, 1997) ; they have developed a PC/Windows-based prototype allowing more functionalities, with a friendly user interface. Before coding, they have

finalised the knowledge structuration thanks to an object-oriented approach and justified their development environment choices by comparing several solutions.

The result is more than a prototype; it has proven to be robust, functional and potentially useful through tests on three simulated Make or Buy decisions.

The software is called « MoB » ; it is described further hereafter.

5 PRESENTATION OF « MOB »

MoB has been developed recently (Davrou and Lefelle, 1997). We shall say a few words about their conceptual and technical choices to fulfil the specification book and describe the main functionalities of the resulting tool.

5.1 Conceptual and Technical choices

Previous results were integrated and consolidated:

- the rule base, whose coherence had already been checked, was considered as an input ; yet, the assumption was made that the software should support further enrichment or updating of the rule-base ;
- uncertainty and fuzziness of the knowledge used to make the decision have been taken into account by three kinds of variables :
 - each fact can be valued in the $[0,1]$ interval, by step 0.1 ; each value is associated to a qualitative scale corresponding to the semantics of the related fact (from *very low* to *very high*) ;
 - the contribution of each fact in a rule is weighted according to its importance (ponderation factor) ;
 - the certainty factor is a percentage attached to a fact which allows to evaluate how certain the value given to a fact is.
- mathematical formulae allow to calculate values and certainty percentages for the deduced facts - till the final decision : Make or Buy? - from the values and percentages attached by the decision maker onto the initial facts.

The knowledge base has been designed through an object-oriented approach ; all the pieces of information appearing in the rules and that are required for taking the make or buy decision have been gathered according to an object structure ; the resulting object model is presented in figure 1.

The development language used was C++, and MoB works in a Windows environment and stores its results in an ACCESS database.

Figure 1: MoB object model in OMT formalism.

5.2 Functionalities

The MoB application has two main modules : one for acquiring knowledge and the other to perform the diagnosis and tune the rules. From the initial screen, these modules can be operated by menus and/or icons (figure 2). More icons allow users to close the active diagnosis, arrange opened windows/diagnosis vertically or horizontally or use contextual help.

Figure 2 : Main screen - the toolbar.

5.2.1 the knowledge acquisition module

Knowledge is acquired according to the objects identified in the object model. The user has to provide information concerning :

- the industrial sectors (company's, suppliers', etc.) and their strategic groups;
- the customers ; attributes are classified by themes : general aspects, financial aspects, design and manufacturing processes, corporate policy, activities/products and suppliers ; for each customer's product, additionnal information is asked ; for each customer's supplier, questions are asked about several attributes of their relationship ;
- the suppliers (same kind of information as for customers) ; and
- the products with four categories of information : general aspects, financial aspects, patents and capacities/competences required.

For all types of information, the user gives two values : the value of the fact itself and a certainty factor translating his confidence on the fact value provided. This can be done intuitively by valuating a potentiometer with the mouse.

5.2.2 The rules tuning and diagnosis module

By clicking on the corresponding icon of the toolbar, the user can modify easily the rules ponderation factors. The whole rule-tree appears in a window, where icons represent deduced facts and represent initial facts. Once selected (left mouse button), facts can be weighted with a valuation potentiometer.

Figure 3 : Diagnosis screen.

To launch a new diagnosis, the user must select a customer company, the product/activity foreseen for Make or Buy, and a supplier, then click on the « execute diagnosis » icon in the toolbar.

The rules inclusive structure, with all facts valuated, appears and the user can access to all steps of the calculation.

6 CONCLUSION

MoB results from a step by step development, with a specifications enrichment through 3 successive studies.

The whole specification and development process illustrates how difficult can be strategic decision modelling, based on uncertain, hardly quantifiable and expertise-based information.

The resulting software, MoB, is a functional and user-friendly tool. We plan to improve it by adding more functionalities : printing, on-line help, rules editor to update the rule-base, and by using the ILOG Rules inference engine. It is also planned to use it in several industrial cases.

Finally, four directions are foreseen for the way after :

- using the software tool in the frame of industrial case studies in order to allow to ground further improvements and evolutions on the end user's needs (as for instance an on-line help or an editor for adding or modifying the rules);
- adding more rules and facts to take other strategic choices than « make » or « buy » into account, as for instance, in an « extended enterprise » paradigm, long term relationship with suppliers ;
- using the MoB software tool for a pedagogical purpose, for training students to make Make/Buy decisions and show them that plenty variables have to be considered simultaneously ;
- adding modules to the tool : the object model has been elaborated in a generic way, so that modules could easily be developed for supporting other manufacturing strategy decision categories, such as capacity or facilities ; and
- generalizing the concept to internal activities : any activity , even internal, has customers and suppliers, and MoB could help determine the strategic importance of the supplier/company relationship.

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