Decision Support Methodology for Early Decision Making in New Product Development – A Case Based Reasoning Approach

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Abstract

A decision support environment aimed to help project managers and design engineers in early stages of product development is proposed in this paper. The research is in the framework of CODESCO - Communication and Decision Support Environment for Managing Concurrent Engineering. A practical methodology for computerised decision support is proposed in this paper. The focus will be on the research carried out to date towards developing a knowledge-based system using the Case Based Reasoning (CBR) approach. We shall describe the generic decision process and how decision data is represented in cases, a typical 'what-if' scenario, which applies CBR in order to study the downstream effects of proposed changes to product specification. The paper concludes by discussing the issues that emerge from this type of approach.

Keywords
New product development, Decision making, Case Based Reasoning

1. Introduction

In a Concurrent Engineering (CE) environment, the product development process is reoriented by involving as much development expertise as possible in the early stages. Liasing design with functions like manufacturing, service, reliability, test results in increasing the complexity of the design process, as more constraints are added and more information must come from these functions. As practice has revealed, many times the product design specification is vaguely defined, incomplete or can change, and design problems are "ill-structured" and "ill-defined". This increases the probability that additional information or changes appear in the product specification in subsequent stages of the design and development process, which can significantly affect the downstream issues of manufacturing, quality, product final cost, product introduction time, and thus, the marketplace success of the product (Parsaei and Sullivan, 1993) So, engineering design decisions as well as management decisions are often made on the basis of incomplete, low quality, and inconsistent information. The lack of information, correlated with time constraints can bring the designer into a critical situation. This is why early design decisions are sometimes made in an empirical manner, using only personal knowledge and experience, and not on a solid basis.

Therefore, a knowledge based decision support system, providing the design engineer and the project manager with accurate and timely information and knowledge, is an important need for early phases of design and development and would make the implementation of CE more productive.

This kind of system and methodology are proposed by CODESCO. The overall objective of this research project is to develop and validate a communication and decision support environment for helping project managers and design engineers working in a concurrent engineering environment. In order to achieve this objective, the following specific aims were defined within CODESCO, ESPRIT project no. 25455. (CODESCO, 1997)

- To capture and analyse typical decisions and decision criteria of the New Product Development process.
- To identify the corresponding communication and decision processes from the project manager's and team member's viewpoint.
- To provide an environment for analysing the effects of proposed changes to product specification and their downstream consequences of the NPD process. This will include a 'what-if' scenario to determine costs and benefits of the proposed changes.
- To collect company specific past project cases, their decisions and their outcomes, in order to set a repository for Case Based Reasoning. The repository will be used in the decision making process by comparing and contrasting past cases with proposed changes to the product specification.

2. Approach

The base for our research was part of the industrial needs and requirements identified at two of the project partners. GDA in UK, a consumer goods company, and TSI in France, producing electronic components for civil and military environments, came into this project with specific and very different product development processes and therefore different requirements for the decision support. Emphasising the changing nature of product specification, GDA specifies as main requirement the framework for studying the consequences of these changes, in the form of 'what-if' scenarios. The various parameters of a specification change would be the input for the system, which should be able to recognise the source of the change. Also the output should be the influence on key parameters, such as overall project lead time, project cost, product cost, tooling manufacturing and assembly, etc. TSI option for the decision support module was to build repositories of past Context / Decision / Results, for the following decisions: decisions for defining a technical solution, decisions for accepting or rejecting a technical solution, decisions about changes of project parameters with or without effects on the contract.

Both companies' requirements comply with our CBR approach and are good and innovative applications of it. Past problems are documented in a base of cases, and retrieved using a reasoning mechanism, in order to match with and as solution for a current unsolved problem. CBR is not only a computer technique, but also a methodology for guided decision making.

In order to meet our objectives, we started by collecting cases through interviews with project managers and team members at the industrial sites. The case structure was built based on the user requirements and the specific literature. Analysing the cases, specific decisions, decision criteria and decision processes were identified. From these cases, but also using knowledge from literature, a generic decision process and a generic 'what-if' scenario for concurrent engineering environments were developed.

For the software implementation, one of the CBR software tools available on the market was selected and is being used for implementation. The final software system will stand for the knowledge based decision support tool and will be tested and applied in both of the industrial environments presented before.

Particular consideration was given to the potential of our decision support methodology and tool to be applied in any integrated product development environment. The decision process and the case structure reflect this consideration, as well as the software implementation will. The approach is illustrated in Figure 1.

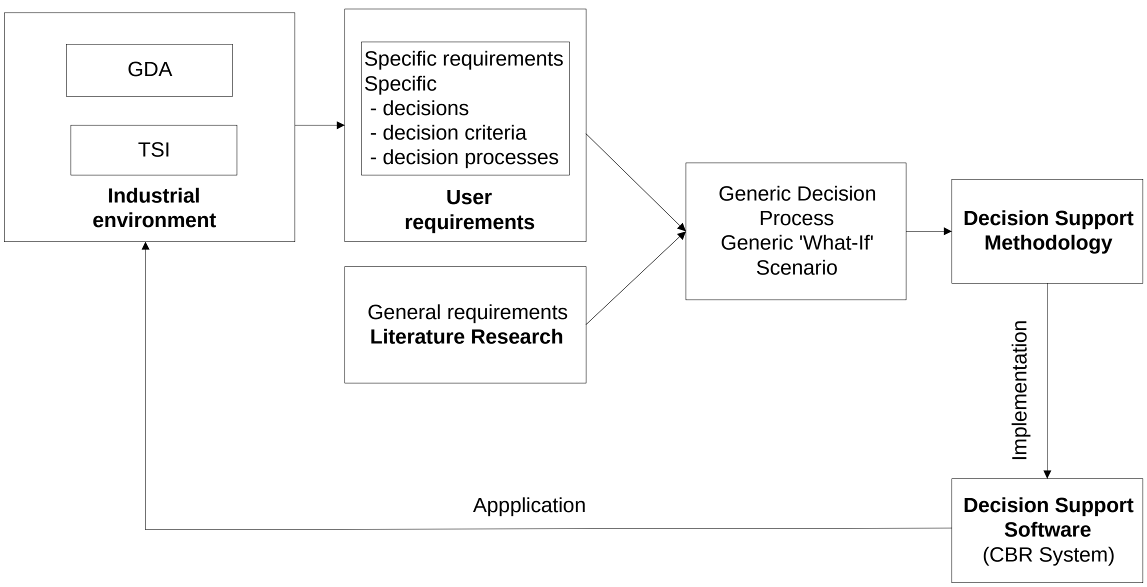

Figure 1: General Approach

3. Decision Methodology

People find easy and natural to use past experience when making a decision, especially if the context parameters are not clearly defined or known. Whether this experience is in the form of intuition, or some other person's expertise, or it comes through a database of rules or guidelines, it usually expresses knowledge about the problem domain. Current computerised decision support tools provide the required knowledge for the decision-maker through rules or through cases. Considering the general complexity of our problem, case-based support approach is found more efficient and easier to implement.

3.1 Case Based Reasoning

For decision support we implement Case Based Reasoning, a computer technique of storing and retrieving cases from a database. The CBR process comprises several steps: cases are stored in a database in a structured way, then a reasoning mechanism performs the matching between these cases and a current problem to solve and extracts from the case base the most similar one. This case should provide the solution for decision making, but an adaptation might be carried out sometimes, after evaluating the solution's suitability for the current problem.

3.2 Definition of case structure

The content and the structure of the cases have great impact on the results. For a more accurate output of the CBR module, highly structured cases are recommended. The case structure was built based on suggestions from literature and on the information which interviews provided. It integrates two perspectives: a 'problem solving' perspective and a 'decision making' perspective. As literature confirms (Bugdhal, 1990), a decision making process appears usually within a problem solving process, as Figure 2 shows, even though there is some overlapping, as it will be explained later.

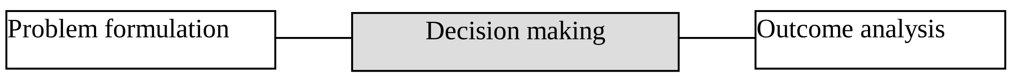

Figure 2: Problem solving process

The *'problem solving'* perspective

Before considering any decision making issues, cases have been built around a problem solving process. Following suggestions from (Kolodner, 1993) the case comprises of three main elements:

- Problem
- Solution development
- Outcome

The '*problem*' part of the case encodes the state of the problem domain as reasoning begins. In our case, it will represent a problem that needs to be solved. A case-based reasoner determines whether an old case is applicable to a new situation (problem), by examining the similarities between descriptions of the problem in the old situation and the new one. Thus, a problem representation must have sufficient detail to be able to judge the applicability to the new situation (Kolodner, 1993). The '*solution development*' part of the case should contain, beside the solution itself, which represents that action or alternative which solves the problem, a set of additional information showing the process of obtaining that solution. Therefore, it incorporates the decision making parameters. The '*outcome*' part of the case specifies what happened as a result of implementing the solution and how the solution performed (Kolodner, 1993). The Figure 3 describes the way that this case structure was developed.

The *'decision making'* perspective

As documented in literature, the process of decision making consists of three phases: *intelligence*, *design* and *choice* (Turban, 1995). In the first phase, the reality is examined and the problem is analysed and clarified, hence the *objectives* are identified. The second phase means inventing, developing and analysing possible courses of action (*alternatives*). The choice phase includes selecting a proposed *solution*. The decision maker uses an *assessment* *method* for evaluating the probable *consequences* of the alternatives, against *selection criteria* (e.g. cost, benefits and risks*)* (Turban, 1995). All this process is actually the formalisation of the way that people *make decisions* and these issues are documented in our cases.

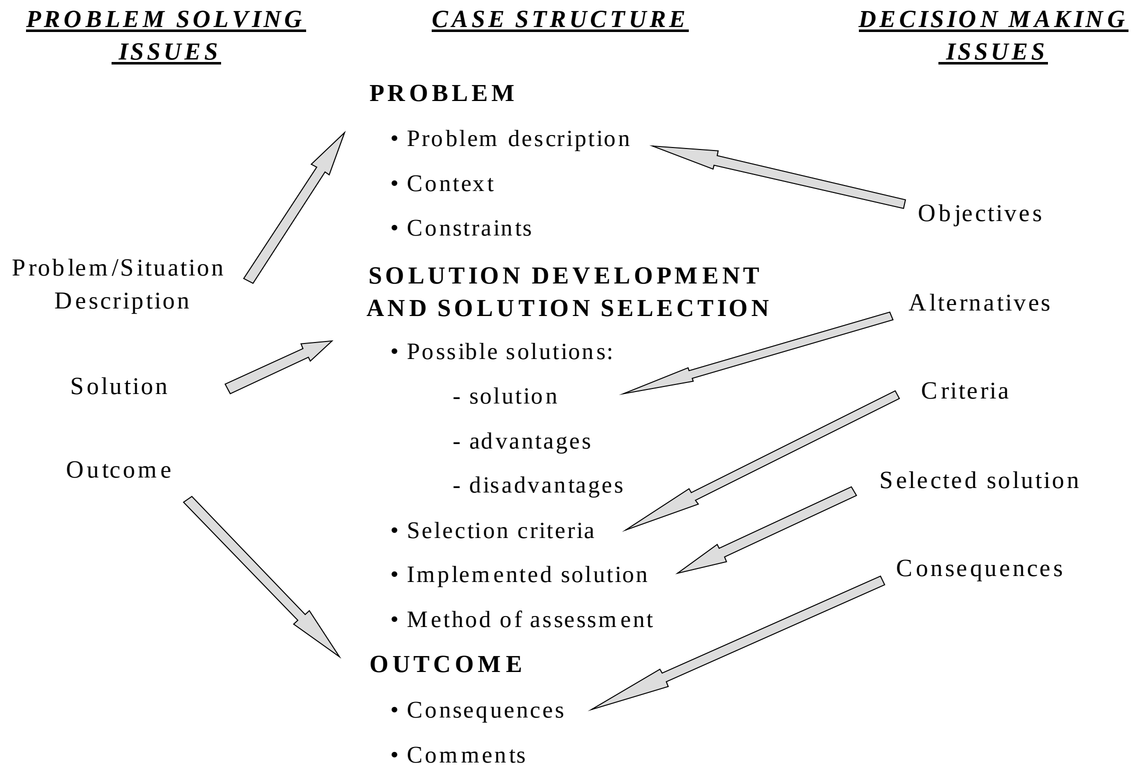

Figure 3: Case Structure

The diagram shows the main attributes, common to GDA and TSI. At this level of detail, cases from both companies and not only can be mapped on this structure. Differences appear when further structuring fields like '*context*' and '*constraints*'. '*Context*' contains fields like '*product details*', '*project details*', that obviously differ in these companies, hence their sub-structure will be different.

3.3 The Generic Decision Making Process

After detailed evaluation of decision making in GDA and TSI and based on literature on decision making theory (Daft, 1995; Turban 1995; Sauter, 1997), a generic model for the decision making process, representative for both sites, was developed. This model (Figure 4) corresponds to the case structure, from both the 'problem solving' and 'decision making' perspectives. Case Based Reasoning supports this process by providing the 'Solution Development' and 'Outcome' parts for a particular case, when the 'Problem' part is given. So, the methodology for decision support is about documenting and presenting in a structured way the steps which a decision maker has to follow, through examples. It therefore provides a history of past similar decision making processes, having potential for discovering a *generic pattern of decision making*, for a particular decision, in a concurrent engineering environment. Decisions in the cases collected to date are made for solving design issues, development, production and maintenance issues, which relate back to design faults or weaknesses. A few cases describe managerial decisions, like choice of technology, make vs. buy decisions, etc. The "*types of decisions*" is one of the criteria for classifying these cases.

Different criteria for decision making were identified: for TSI, two major issues are the client's satisfaction and the cost for TSI, whereas in GDA, the main parameters for decision making are the development time, since they have very short product development lead times, and the tooling costs.

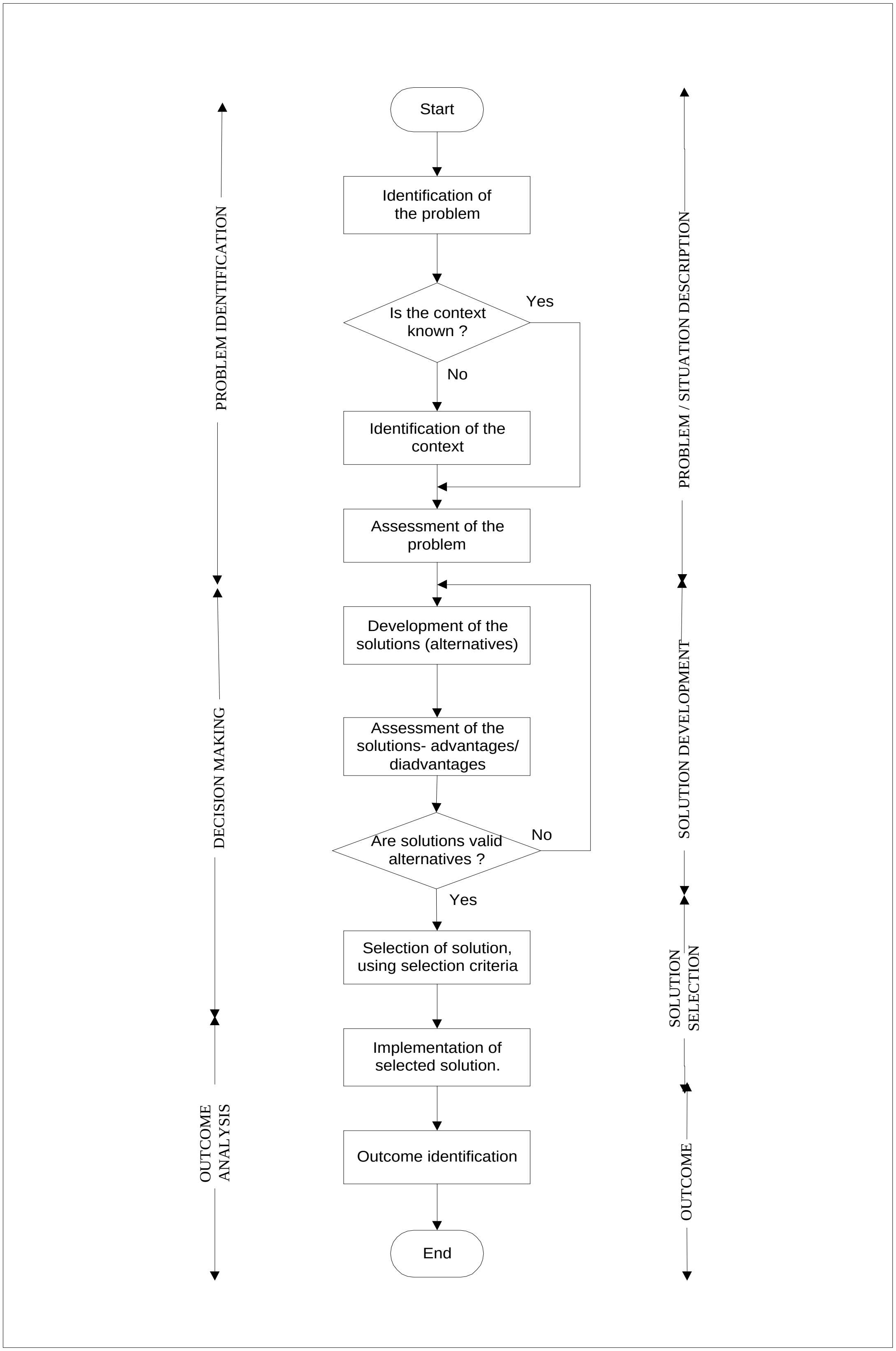

Figure 4: Generic Decision Making/Problem Solving Process

4. The 'What-if' Study

Figure 5 describes a methodology for using (retrieving) cases from the case base, in order to find the consequences of particular decisions or design (specification) changes which cause problems that need decisions. The main idea behind this methodology is that many times design problems appear as *effects* to some *changes in product specification*. Therefore, another way to describe a problem (and this is a requirement for using this methodology) is in terms of *'design'* or *'design change'*, which caused the *'consequence'* or *'problem'*. Solutions to these problems can be many times to make a change in the design (like redesign a component, modify the configuration of a subassembly, etc.). Then, as part of the case, the outcome of this solution (change) is documented, showing whether the solution implementation was a failure or a success. This scenario can continue depending on the availability of cases and on how positive the outcome is (negative consequences are new problems to be investigated).

So, an 'what-if' study can be done by retrieving cases which show the consequences of some changes, or vice-versa, retrieving cases which contain the change that had impact on a particular issue. The mechanism behind is again CBR, hence identifying scenarios that have happened in the past, in similar contexts, and for similar design changes. Through a sequential querying of the case base, the user can see and analyse the dynamics of the design changes and consequences. This is also a guide for using the CBR module, but and the steps can also be automated by extra software implementation.

The strengths of this methodology are that it guides the user through a structured and systematic process in making decisions, eliminates ambiguities, improves the consistency of decisions and increases the likelihood of making correct decisions, enables the retracibility and repeatability. Moreover, to apply this methodology and to use the CBR system does not require domain expert knowledge.

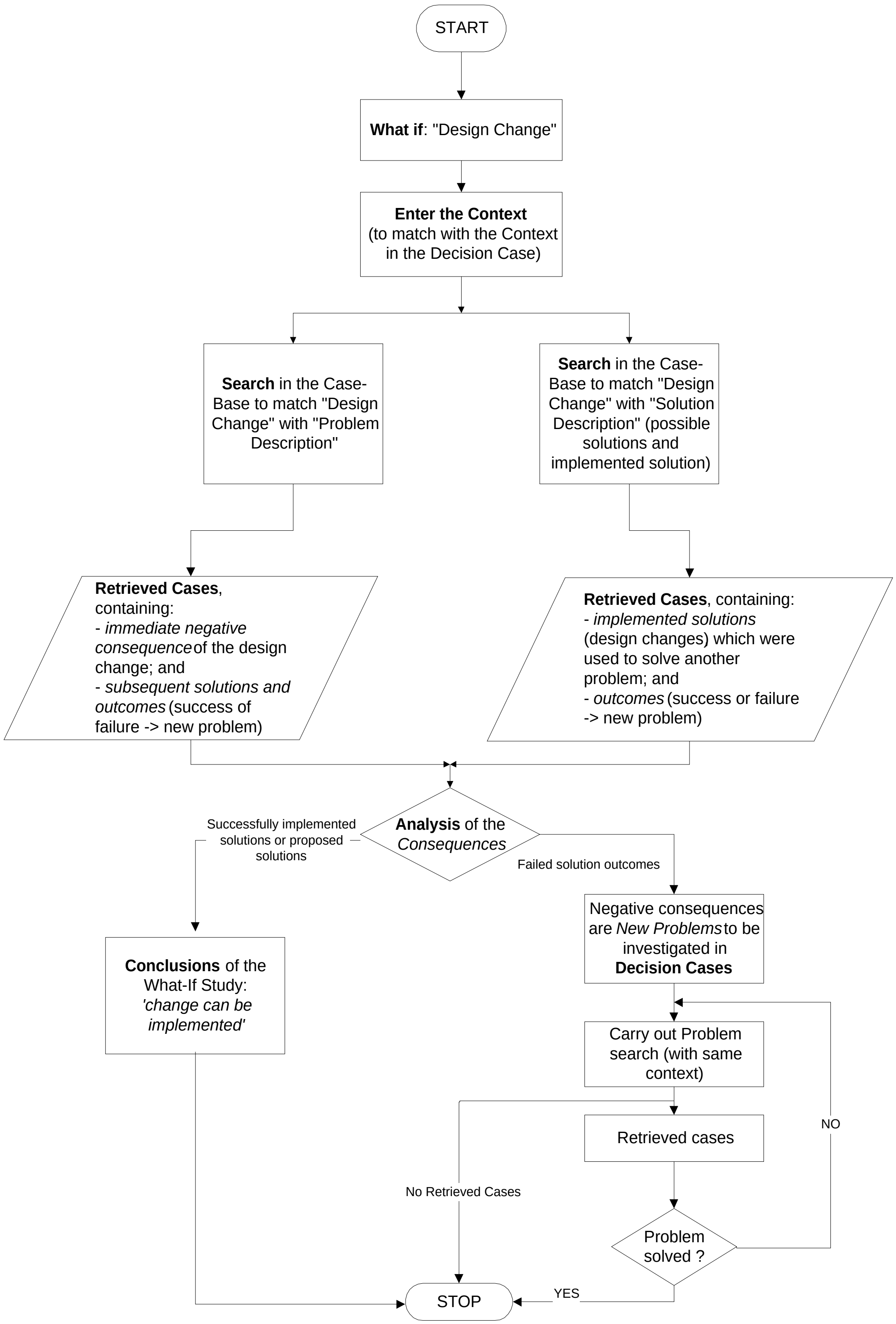

Figure 5: What-If Study

5. Conclusions

The paper discusses the developments carried out to date for building a decision support environment for design and management problems, through a Case-Based Reasoning methodology. We base our research on two contrasting industrial companies, (GDA, a fast moving consumer goods company, and TSI, a program orientated one-of-a-kind environment). We analysed the commonalties and differences and developed a generic methodology, which, innovatively, addresses issues from both sites. The methodology is based on past experience recall and uses Case Based Reasoning. Its efficiency relies on how the case structure was built. We are currently testing the applicability and the relevance of our case structure and reasoning mechanism through cases coming from these companies. The decision support system will facilitate identification of consequences of decisions and consequences of specification changes on downstream product development issues, and will allow for retracebility on the cause-effects chain.

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