# An Intelligent System For Bid Management

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## ABSTRACT

*Managing change in a complex business environment presents real challenges. Chief amongst these is the pace of change in terms of technology, management innovation and the whole competitive environment. Understanding how the business operates makes it possible to identify and address areas that are restraining business performance.*

*Enterprise modelling methods capture various aspects of how a business works and how it is organised. This helps to obtain an enterprise-wide view of an organisation, which can then be used as a basis for taking decisions. AIAI at the University of Edinburgh lead the Enterprise project, which focused on management innovation and the strategic use of IT to help manage change.*

*AIAI and Pilkington Optronics worked together to demonstrate how the approach of the Enterprise project could be used to address Pilkington Optronics's real business needs. This lead to the development of the Bid Manager system which supports the bid / no-bid decision. By basing the Bid Manager on the Enterprise Toolset, Pilkington Optronics have been able to obtain a system that integrates existing IT application systems, enabling them to upgrade the overall system as their business processes develop.*

## INTRODUCTION

Managing change in a complex business environment presents real challenges. Chief amongst these is the pace of change in terms of technology, management innovation and the whole competitive environment. Understanding how the business operates allows you to identify and address areas that are restraining business performance. Some key problems are:

- how to overcome communication barriers between people in an organisation,
- how to achieve consistency in operational processes,
- how to manage the wider impact of change,
- how to enable IT systems to evolve at the same pace as the organisation, and
- how to develop a responsive business.

Pilkington Optronics experienced many of these problems. They design and manufacture high-tech, electro-optical systems, including thermal imaging and submarine periscopes. Through the mid 80s the company was in profit, but as the market changed with the end of the Cold War they found themselves in "the red". Pilkington Optronics undertook a fundamental review of their organisation and processes and developed a 10 year strategic plan to address the underlying problems, and were looking for support to implement the plan.

Pilkington Optronics approached AIAI for assistance with their management of change. The work described in this paper was carried out as part of AIAI's Enterprise project.

## THE ENTERPRISE PROJECT

The Enterprise project was the UK government's major initiative to promote the use of knowledge-based systems in enterprise modelling. AIAI at The University of Edinburgh lead the project and their partners were IBM, Lloyd's Register, Logica and Unilever. The project focused on management innovation and the strategic use of IT to help manage change[1,2]. It supports the use of enterprise modelling methods which capture various aspects of how a business works and how it is organised. The aim of enterprise modelling is to obtain an enterprise-wide view of an organisation which can then be used as a basis for taking decisions.

During the Enterprise project, the Enterprise Toolset was developed[3]. The Toolset uses executable process models to help users to perform their tasks. The Toolset is implemented using an agent-based architecture to integrate off-the-shelf tools in a plug-and-play style.

The approach of the Enterprise project addresses the key problems of communication, process consistency, impacts of change, IT systems, and responsiveness. The components of the Enterprise Toolset are:

- a Procedure Builder for capturing process models,
- an Agent Toolkit for supporting the development of agents,
- a Task Manager for integration, visualisation, and support for process enactment, and
- an Enterprise Ontology for communication.

The **Procedure Builder** is a graphical tool for describing and recording business process models. It allows the user to build process diagrams using the notation of Process Flow Networks (PFNs) as specified in the IDEF3 Process Description Capture Method[4]. The Procedure Builder also allows users to specify information which is specific to the needs of task management, in particular the capabilities required to perform a process and input and output specifications of the process. To represent the process information we developed a process modelling language. In developing the language we took account of emerging standards, such as PIF (Process Interchange Format[5]) and WAPI (the Workflow Application Programmer's Interface developed by the Workflow Management Coalition[6]). The output from the Procedure Builder can be exported for use directly by the Task Manager. In addition the Procedure Builder can produce reports containing the process diagrams and associated process information.

For the agent-based architecture of the Enterprise Toolset we investigated a variety of externally available solutions and concluded, at that time, that none of them was mature enough to use as-is or met all our requirements. We therefore developed our own agent-based solution which is supported by the **Agent Toolkit**. One of the essential principles guiding its design was to make the creation of new agents as easy as possible. We wanted to be able to support as-yet unspecified tools as agents without any redesign of the Agent Toolkit or any other component of the Enterprise Toolset in order to accommodate these new tools. We also wanted to ensure that an organisation's existing applications and tools (i.e. their legacy systems) could be accommodated.

Keeping in line with emerging standards, the agent communication language we support is KQML (Knowledge Query Manipulation Language[7]) and messages are expressed using KIF (Knowledge Interchange Format[8]) and the Enterprise Ontology (see below).

There is also an Agent Registration Tool to make agents (software or human) available to the Enterprise Toolset, specifying details about the agent, such as its capabilities. The agent-based architecture allows agents to be added to and removed from the overall Toolset in a plug-and-play style.

The **Task Manager** is the interface between the user and the Enterprise Toolset. It directly supports the user in performing their current tasks. The Task Manager plans user tasks and the use of agents. Information about tasks is available from the process models specified through the Procedure Builder, and information about agents becomes available when agents are registered. Appropriate agents are identified at run-time at the last possible moment, so that the most suitable agent can be identified, taking into account which agents are available at that time. The Task Manager also handles outputs generated by tasks. It stores such output information and it can pass it on to other tasks that require the information.

The Task Manager monitors the progress of a task's enactment, keeping track of which tasks are currently active, which have been completed, etc. This progress can be visualised in different ways, the visualisation being supported by the process diagrams captured with the Procedure Builder. The amount of support that the Task Manager gives to the user is flexible and can be adjusted by the user. Advice on what to do next is available on the basis of which tasks are ready to be executed and which have recently been completed. The Task Manager can also help the user to recover from failures, determining alternative routes of action.

The Task Manager effectively puts an extra layer of control on top of the agent services. It coordinates the use of agents at the level of the user's tasks and lets the user participate in this coordination, according to the tasks in which the user is engaged.

We require an effective communication mechanism to achieve integration of a wide variety of tools, both new and old. Independently developed tools are likely to use different terminology which can lead to conflicts and ambiguity. To resolve such issues, a standard terminology is required when tools are integrated. An ontology provides such a standard terminology[9].

We developed the **Enterprise Ontology** for use in the Enterprise Toolset[10]. It is a set of terms frequently used in enterprises, each carefully defined to conform as best as possible to common usage. We have concentrated on the areas of organisation, strategy, activities and processes, and marketing. We did not try to define all terms that are likely to be required; the terms we defined are ones that we expect to be generally useful. Every organisation will have their own set of terms that they use, so the ontology can be extended to suit the specific needs of the organisation. Committing to this ontology has the advantage that terms are used consistently and unambiguously throughout the enterprise. The ontology thus provides the basis for communication between agents, whether they are human or software agents.

Figure 1 shows the overall architecture of the Enterprise Toolset. The boxes represent software modules, the diamonds models and information, and the ovals user types. For clarity, the Agent Toolkit has been omitted from the diagram.

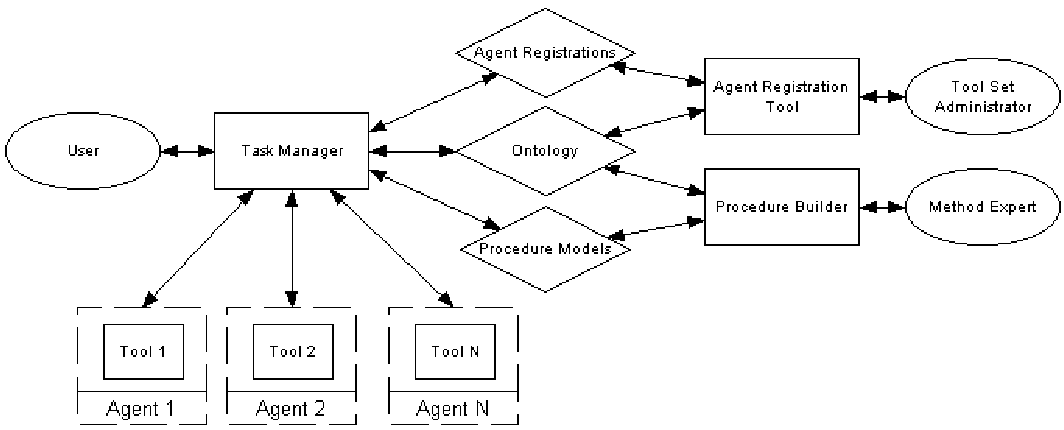


**Figure 1: Enterprise Toolset Architecture**

## THE APPLICATION

AIAI and Pilkington Optronics worked together to demonstrate how the approach of the Enterprise project could be used to address Pilkington Optronics's real business needs. One of the core areas of concern at Pilkington Optronics is the decision process of bidding for work—should they bid or not. This bid / no-bid decision is based on an evaluation of the risks and opportunities involved in the potential project and the bidding process itself. It is not concerned with preparing the bid or with the decision of whether or not a bid is accepted (this decision is outside the scope of this paper because it would be taken by the customers, not by Pilkington Optronics itself). In this paper, a "bid" is a *potential* bid, i.e. a bid that Pilkington Optronics may or may not decide to prepare.

At Pilkington Optronics, the amount of work that is done on a potential bid before a decision of whether or not to bid is reached varies widely. Some bids are decided almost immediately (perhaps on the telephone) whereas others are worked on for months or even years before a decision is reached. This means that the amount of information available for a potential bid also varies.

During bid management, there are two categories of activity based on the nature of the results they are expected to achieve:

**Activities that improve analysis:** these are information gathering activities which result in improved quality and reliability of bid information. These activities contribute to making better decisions, but do not themselves increase the likelihood of Pilkington Optronics winning any bids.

**Activities that improve position:** these are activities that result in an improved bidding position in terms of likelihood of Pilkington Optronics winning actual bids.

A decision of whether or not to bid should be based on the knowledge of:

- what information is available and how reliable it is
- how Pilkington Optronics is placed for winning the bid considering the available information.

This indicates that bid management is mainly concerned with the gathering, management, and analysis of information. At each point during bid management there is a wide choice of which aspect of the bid to work on next and often the order in which issues are addressed has no impact on the outcome of the process.

At the start of this project, there was no IT support for the bid management process at Pilkington Optronics. There are IT systems that hold some of the information that is relevant to bid management (such as in-house skills and staff availability), but there is no overall support. Pilkington Optronics felt that the process of bid management was a key process in their business, but it was poorly supported. Many bid / no-bid decisions were taken mainly on the basis of gut-feel and the scope for mistakes were too great. Pilkington Optronics were looking for an IT solution that could keep pace with changes in the business, its strategy and processes. This application was chosen as an example of how enterprise modelling techniques can be used to support a decision process.

## BID MANAGEMENT SUPPORT

We have shown above that during bid management it is important to know what information is available, whereas the decision of which issue to work on next is often arbitrary. This means that it is impossible to specify a useful sequence of steps to follow and that bid management is not suited to procedure-based support.

The closest we can get to a procedural view on the overall bid management is to describe the overall process on a very high level:

1. select a bid to work on or start a new bid,
2. select an issue of the bid to work on,
3. work on the issue,
4. update the issue,
5. go back to 2 or finish working on the bid.

It is easy to see that this description is of limited use to support the decision making process.

If instead of the procedural view we take an information-based view of bid management, a different kind of support can be provided. Visualising the information available together with its reliability, managing updates to information, providing overviews of the current position, and showing how the position changes over time can be supported based on the information available and on knowledge about the information.

The actual activities of bid improvements (analysis or position) are a different kind of problem. Such activities are concerned with the processes of gathering information and making changes that affect the current position. These activities are concerned with “doing things” and are thus much more process-based. Performing the improvements may therefore involve procedures for which workflow support can be provided.

The Bid Manager system takes an information-based approach to supporting bid management at the top level, and a process-based approach to supporting the lower level activities of bid improvement. The Bid Manager provides six areas of support for the bid/no-bid decision.

1. An information model is provided as an explicit representation of issues to be addressed. This helps users to remember which issues to address and it is used to store the outcome of addressing issues. For the system it is the basis of all other support.
2. The information currently available for the bid is shown at all times so that the user is informed of the current state of the bid. Different views are provided for different kinds of information to help users understand and analyse the information available. This has two purposes: to determine what the bid/no-bid decision should be given the information currently available, and to identify issues which should be addressed next.
3. Editors are provided so that it is easy for users to provide new information about the bid. Updates are reflected automatically in the information views provided.
4. There are some checking mechanisms to ensure that information provided by the user through the editors is correct.
5. Two agendas are maintained for bid improvement, presented as ranked lists of issues. One list shows issues whose analysis should be improved, the other shows issues for which Pilkington Optronics’s position should be improved. These lists help users decide what to do next to improve the bid.
6. There is a connection to the Enterprise Toolset and its agent-based task management system which provides process support for improvement activities and provides access to other tools that may be required during improvement activities.

Figure 2 shows the architecture that provides the areas of support (shapes mean the same as in Figure 1). The following sub-sections provide some more detail for these areas of support.

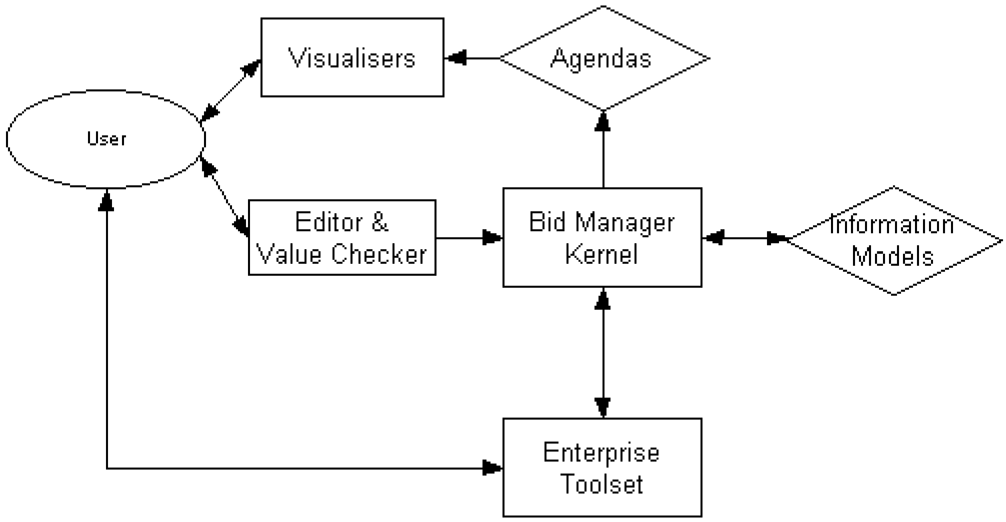


**Figure 2: Bid Manager Architecture**

## *INFORMATION MODELS*

We have identified *issues* on which decisions of whether or not to bid are based at Pilkington Optronics. During bid management, more and more of the issues are addressed to more and more depth until a final decision is reached. These issues can be organised into a hierarchy of issues and sub-issues, called a *decision tree*. Examples of high-level issues are "Doability", i.e. is Pilkington Optronics in a position where they can do the required work on the bid and the program, and "Winnability", i.e. is Pilkington Optronics in a position where they can win the bid against their competitors. Lower-levels include issues like "Technical Specification" and "Customer Relationship".

Throughout the life-span of a bid each issue in the decision tree always has a current value which reflects the current opinion of how well Pilkington Optronics is placed for this bid with respect to the issue. There are three possible values: "good", "satisfactory", and "poor". These values were chosen because they are intuitive and appropriate to reflect the relevant information. The value "good" is taken to mean that on the strength of this issue the decision would be to bid, so that if all issues in a bid are "good", the bid will be prepared. The values of "satisfactory" and "poor" both reflect that the position could be better and thus should be improved (with different urgency). A "poor" value will, in most cases, force a no-bid decision, whereas a "satisfactory" one may not. Values of issues will change over time as more information becomes available or as the position is improved for the issue. Therefore, issues of a particular bid will have a *history of values*.

For each value there are two important aspects: the value itself, i.e. the current position of Pilkington Optronics with respect to the issue and information about how the value was established. The second aspect refers to the *source* of the value and provides information about how much confidence can be placed in the value. Examples of sources are "historical data", "opinion of customer", and "assumption". Sources of values are organised into categories according to their quality, i.e. how reliable the information they provide is. The categorisation of sources can be different for different issues, i.e. a source can be categorised as "good" for one issue and "bad" for another.

Values of issues can be propagated through the decision tree, i.e. the values of high-level issues can be inferred from values of their sub-issues. Our strategy for propagation is very simple: the worst value of the sub-issues is used on a higher level. This is a conservative (pessimistic) approach which ensures that we only take a decision to bid when this decision is well supported. Propagation of values through the hierarchy means that for higher-level issues there are two ways of reaching a decision: addressing the issue itself or addressing its sub-issues.

## *BID PRESENTATION AND UPDATES*

Information is presented in different ways so that different aspects of the bid can be grasped at a glance. There are three major visualisations providing information at different levels of detail:

1. The decision tree is shown as a colour-coded diagram which provides a summary of Pilkington Optronics's current position with respect to all issues of the bid (Figure 3; colour removed). Colours represent the current value of the issue: green for "good", yellow for "satisfactory", and red for "poor".
2. The Bid Manager's main window contains a display which provides details for the sub-issues of one focal issue. The main part of this display is a colour-coded matrix showing Pilkington Optronics's current position together with the quality of the information source (Figure 4). Each sub-issue has one coloured box in its row. The position of the box shows the value ("good", "satisfactory", or "poor"), the colour shows the quality of the source. The brighter the colour the better the source and the more confident we are of the value. (In the gray

scales of Figure 4 this translates roughly into the darker the better, which is not as intuitive as the colour version.)

3. Full details are shown for one issue, including the current position, the information source, notes, and a history of how Pilkington Optronics's position changed for that issue during the history of the bid (Figure 5).

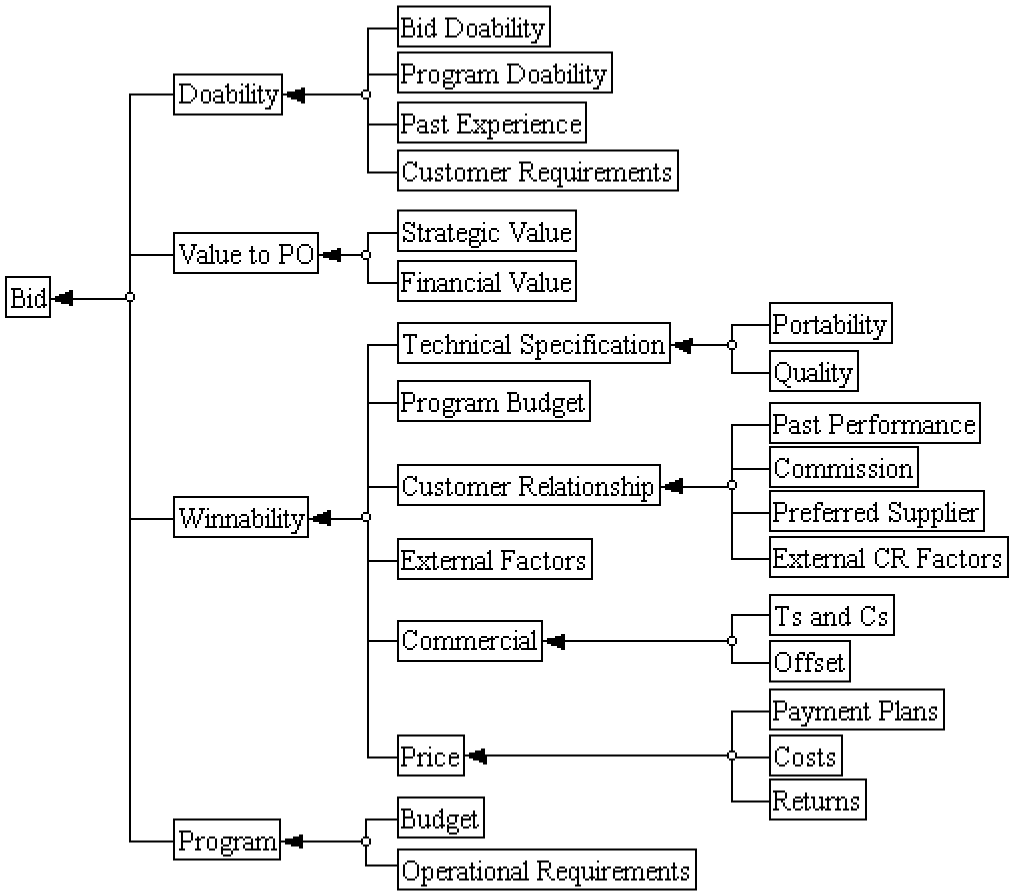


**Figure 3: The Decision Tree**

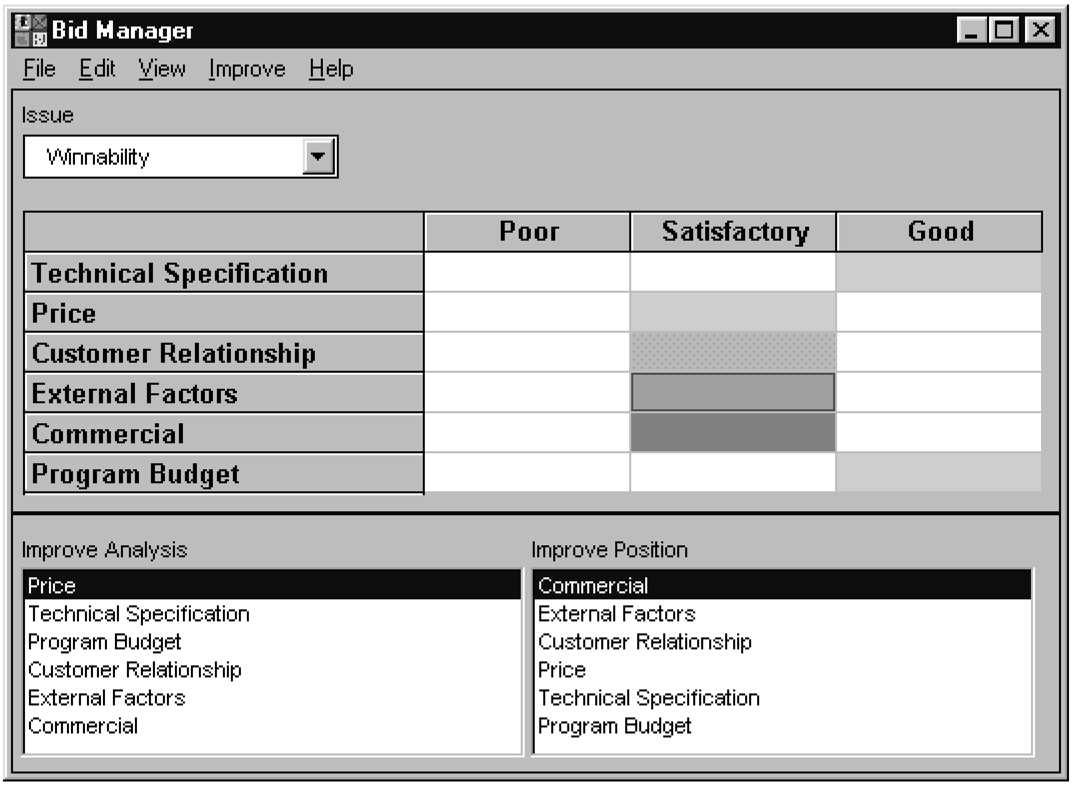


**Figure 4: The Main Window**

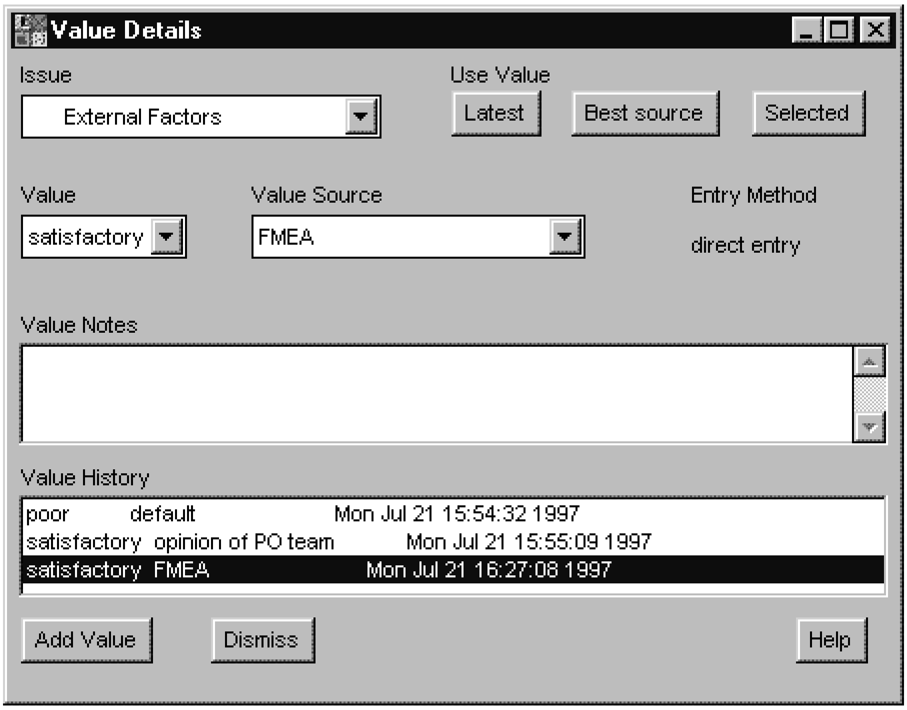


**Figure 5: Issue Details**

The different displays can be used to manipulate other displays. For example, clicking on an issue in the decision tree will make that issue the focal issue in the main window such that more details of its sub-issues are displayed.

The display for issue details can be used to update issues. Updating an issue is done by selecting a new value and its source from provided lists, and typing in notes to be attached to the value. Updates take effect when they are submitted to the Bid Manager, at which point the new value is added to the history of values in the display. The new value becomes the current value of the issue and the changes are reflected in the other displays. Note that if a previous value is supported by a different source, the value-selection would stay the same as before; only the source (and notes) would change, but the value would be treated as a new value and would thus be added to the history list (see the second and third line in the history list in Figure 5).

When an issue update is submitted to the Bid Manager, it checks whether the new value makes sense by comparing it to previous values of the issue. If there already is a value with a better source this indicates that there may be a mistake and the Bid Manager will produce a warning and ask the user to confirm the change.

The history of values is maintained automatically by the Bid Manager, but the user can choose to go back to using previous values. This allows for what-if analyses and exploration of alternatives. Unfortunately, it also allows users to "cheat" to ignore unfavourable values. However, values cannot be erased from the value history, which means that there is a record of values which can be audited, and overrides can be detected. In addition, the Bid Manager is used as a tool to support human bid managers in their own decision making process, not as a replacement or a justification for their decisions. The purpose of such "cheating" is thus questionable.

### *AGENDAS*

At each point during bid management, there are two alternatives for improvement actions:

1. improve the analysis of an issue, i.e. find out more about the issue, and
2. improve the position Pilkington Optronics has with respect to an issue, i.e. make changes in the real world in order to improve the bid.

For example, *improving the analysis* of the issue "Program Doability" involves—among other things—checking which skills are required and whether the skills are available in-house. Further analysis checks whether there are enough people with the required skills and whether they are available at the right time. If this analysis shows that not all required skills are available, Pilkington Optronics's position with respect to program doability of the bid would not be good. In order to *improve the position* of the program doability, Pilkington Optronics may decide to obtain the missing in-house skills (train employees, employ new people) or to contract out the work that requires skills that are not available.

Working with a bid, one of the difficult decisions is what to improve next. There is no definitive answer to this question, but potential improvements can be ranked according to how urgent they are: issues with the poorest analysis are most urgent for analysis improvement and issues with the poorest position (value) are most urgent for improving the position. However, a poor position for an issue which has not been analysed much may turn out to be better than expected, so it can be said in general that some amount of analysis should be done before steps are taken to improve the position. The Bid Manager maintains two agendas of issues in its main window (Figure 4), one each for the two types of improvement. All issues are ranked in these agendas according to the criteria above. These agendas are the first step for supporting bid improvement processes. Further support is described in the next sub-section.

### *PROCESS SUPPORT FOR IMPROVEMENT ACTIVITIES*

So far we have addressed the problem of supporting those tasks within bid management that are concerned with understanding the current position of the bid and what information the position is based on. Another important area is the management of bid improvements. The tasks of carrying out improvements may be complex and may require the use of applications like databases or analysis tools. In such cases, it is useful to formulate procedures for carrying out bid improvement tasks.

For example, there is a procedure for improving the analysis of the bid's program doability. There is a sequence of steps and there are alternatives for what to do. Many of the steps involve lookups in databases and analysing the results of these lookups. The Enterprise Toolset with its Task Management component is well suited to provide support. It will:

- offer a list of possible next steps,
- monitor and visualise progress, i.e. keep track of what has been done,
- provide access to applications or - where possible - run them on behalf of the user,
- pass information from one step to another, and
- handle alternatives of how to progress.

Whenever the user indicates that she wants to carry out bid improvement activities, the Bid Manager asks the Enterprise Task Manager whether there is any support available for the specific improvement activity. If there is, the Bid Manager hands over control to the Task Manager which will look after the enactment of the activity's process. In the example of improving the analysis of the "Program Doability" this involves the use of several databases, including one that can match skills to products, an in-house skills database, and a database containing information about staff availability. With the help of the Enterprise Toolset, such databases are easily accessible. Many lookups can be done on behalf of the user and results of lookups be used as input to further queries. When the process is finished (successfully or not), the Task Manager will pass control back to the Bid Manager, together with the results of the activity.

## BENEFITS

In summary, the Bid Manager system with its connection to the Enterprise Toolset provides support for:

- well-structured models of the area of bid management,
- effective visualisation of relevant information,

- easy editing, including some checking for updates,
- automatic updates across different displays,
- advice on which issue to work on next,
- process support for working on issues,
- integration of and access to relevant tools and applications.

This helps users to:

- understand what the current position is with respect to the bid issues;
- understand what information this position is based on;
- understand how much confidence can be placed in this position;
- update issues as information improves or as the position changes;
- keep track of updates;
- perform what-if analyses to determine how changes affect the overall position;
- improve the bid;
- use relevant tools and applications more effectively.

Using an information-based approach to support the decision making in bid management proved to be an important decision for providing useful support. Recognising the most suitable way of representing and visualising an issue is one of the most important steps in any modelling exercise[11], but in an area as comprehensive as enterprise modelling it is especially important.

The initial modelling of the issues related to bid management was useful to Pilkington Optronics. During this modelling, several issues emerged in addition to those recognised previously. One example is the high-level issue of "Value to PO". These additional issues are now taken into consideration during bid management.

The Bid Manager not only supports the bid / no-bid decision, but also provides more comprehensive support which covers the mechanisms of bid improvements as well as the information management aspects of the decision making problem.

## CONCLUSION

The Bid Manger system was demonstrated to Pilkington Optronics in December 1996. Dave Rimmer, Head of Process Development at Pilkington Optronics made these comments on the Enterprise project and specifically on the Bid Manager system:

> "The aim of our operational strategy is to achieve total integration, but so far we have been unable to find an affordable IT solution which meets all our needs. The Enterprise project caught our imagination as it offered an approach which builds on existing data and systems. This gives us the flexibility to integrate new processes and new systems as the business needs change. Also, Enterprise offered us an excellent opportunity to understand how emerging information technology can be used pragmatically to improve management decisions. One such key issue for us is how to select which new business opportunities to follow up. Enterprise has helped us here by focusing on the elements of quality decisions: by defining what information is required; identifying the source of that information; and having a clear statement of its value. The tool we have developed consolidates many critical factors including individual experience and knowledge into a disciplined approach. All of this is geared towards communicating the key issues to our management, and providing traceability for future referenced or reassessment."

By basing the Bid Manager on the Enterprise Toolset, Pilkington Optronics have been able to obtain a system that integrates existing IT application systems, enabling them to upgrade the overall system as their business processes develop.

## ACKNOWLEDGEMENTS

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