Operational intelligence discovery and knowledge-mapping approach in a supply network with uncertainty

Received October 2005
Revised December 2005
Accepted January 2006

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Abstract

Purpose – The purpose of this research is to propose an approach for discovering operational intelligence and knowledge mapping in a supply network with uncertainty.

Design/methodology/approach – Knowledge mapping and handbook techniques are used. TAPS software is used to model a supply network with uncertainty and to discover operational intelligence in a supply network.

Findings – Knowledge management is inadequate for managing a supply network with uncertainty. Knowledge mapping is proposed, but it needs to be assisted by operational intelligence.

Practical implications – iTAPS provides managers with an ability to visualise the operational intelligence for a given objective, and to identify the likely effects on implementing a particular tool or technique in a supply network.

Originality/value – A new approach – called the "intelligence handbook" is proposed to discover operational intelligence in order to map knowledge in a supply network with uncertainty.

Keywords Knowledge management, Knowledge mapping, Uncertainty management, Supply chain management, Decision making

Paper type Research paper

1. Background

The performance of today's global supply network is affected by an increased number of uncertainties. Koh and Saad (2004) defined uncertainty as any unpredictable event that affects the performance of an enterprise. In an economy where the only certainty is uncertainty, the one sure source of lasting competitive advantage is knowledge (Nonaka, 1998).

By taking a "zoom-in view" of a simple example: a supply network that consists of a manufacturer from China and a distributor in the UK, it can be noted that various types of uncertainty may affect the performance of such a supply network. For instance, the logistics issues on ability to deliver on-time, the expected quality in the UK, and others. It is clear that the setting up of a supply network process is connected to the presence of operational interdependencies between the units of the supply chain, the stability and effectiveness of a supply network is closely bound to the ability of the core firm to plan

Journal of Manufacturing Technology Management
Vol. 17 No. 6, 2006
pp. 687-699

1741-038X
DOI 10.1108/17410380610678747

the governance structure of the supply relationship, and the product structure and the nature of the process influence the networking process (De Toni and Nassimbeni, 1995). This phenomenon calls for a better understanding of the operations and characteristics of a supply network with uncertainty, so that a more accurate knowledge can be mapped and a better decision can be made.

Following with this notion, much past research has been carried out proposing various methods of knowledge management in a supply chain. Thannhuber *et al.* (2001) developed an autopoietic approach for building knowledge management systems in manufacturing enterprises. It was suggested that through understanding of the knowledge at the enterprise level, one could cope with dynamic changes of market demand, process design, capabilities in diverse locations, and associated fluctuations in internal process adaptations. Their work has also indicated that instead of focusing on individual human knowledge, the ability of an enterprise to dynamically derive processes to meet the external needs and internal stability is identified as the organisational knowledge. It was proposed that this autopoietic approach could be used in managing a supply network.

Towill (1996) suggested that an industrial dynamics modelling of real-life supply chains is a powerful methodology for predicting and prioritising methods of reengineering the chain to achieve enhanced performance when viewed from the perspective of all players in the chain. However, building an adequate model of an existing or proposed real-life supply chain requires the use of people-based resources, observation-based resources and systems knowledge-based resources. Therefore, it is important to be able to map the knowledge of a supply chain particularly in a global supply network with uncertainty.

Automotive multinational firms increasingly engage in transferring their supply management practices across countries within their global network of operational units. Pagano (2003) provided an in-depth qualitative analysis on such transfer outcomes and on relevant factors shaping such processes. The case of a component automotive manufacturer in China was investigated. The results showed that the transfer process has concerned mainly the supply chain decision-making procedures and those areas linked to the production phase including delivery/logistics and quality control. Using the concept of knowledge transfer, Graziadio and Zilbovicius (2003) compared the supply system in two plants of a single car assembler: one is modular and the other is conventional, both producing sub-compact cars. The modular plant has the highest level of outsourcing. Modular supply demands more interaction between assembler and systemist (also called modular supplier) whenever the logic of outsourcing is present. As long as the assembler transfers more responsibilities for design, purchasing and production to the systemists, the flow of information has to be very efficient. The volume and intensity of knowledge transferred from assembler to systemist also depends on the systemist's role.

Using the concept of knowledge sharing, it was argued that supplier performance will benefit most where time-bound relational assets have developed between a buyer and supplier and the firms exploit the resulting communication, efficiency by transferring productive knowledge (Kotabe *et al.*, 2003). In that study, the effects of two forms of knowledge exchange were also examined, together with the prior duration of the buyer-supplier relationship. Similar interaction patterns were found in two survey samples of Japanese and the US automotive suppliers.

Nath *et al.* (2005) studied the supply chain management of two automobile manufacturers in India and traced the relationship between supply chain and knowledge chain management. The efforts of building up the supply chain were examined under three broad headings namely, knowledge hierarchy, geographical proximity and cultural reorientation of the supply chain. An enterprise's knowledge domain, defined as critical, sub-critical or common market knowledge, was related to various organisational forms.

As the North American automotive manufacturers transfer more responsibility to major suppliers while at the same time experiencing significant engineering personnel reductions due to layoffs and retirements, the industry landscape begins to change (Belzowski *et al.*, 2003). It was recommended that companies must understand thoroughly the value of knowledge within the organisation; acknowledge likely gaps between the perceived benefits and reported knowledge activity levels; resolve discontinuities in knowledge sharing activities between the company, its customers and suppliers; take into account differing emphases by the company, its customers and suppliers on people, technology, process and culture as facilitators of knowledge activities; and measure knowledge activities in order to manage them effectively.

It must be noted that increasing globalisation of aerospace supply network could also be identified. This is particularly true in the outsourcing of engineering and manufacturing operations. In this type of outsourcing project, the effective use of knowledge across the supply chain is crucial. Fan *et al.* (2000) studied the different types of supplier knowledge in the five key stages of the aerospace product development process, and used an existing joint supplier improvement information system to illustrate best practice in supply base management.

Outsourcing has not only dominated the manufacturing industry, but has equally dominated the service industry. For examples, outsourced of call centres and software development to India, are amongst the most practised operations. Koh *et al.* (2004) developed a knowledge management model for effective service performance for a call centre. Such operation also requires an effective knowledge management procedure in order to protect innovations capability and service performance.

2. Research gaps, aims and objectives

It can be synthesised from the above literature review that little research has been carried out on knowing mapping. Simply identifying and managing the relevant knowledge in an enterprise or supply network will not be suffice because of the inter-relations of business functions and operations in a supply network, particularly one with uncertainty and with many tiers. Without proper mapping of knowledge, the causes and effects of uncertainty in a supply network may not be clearly understood, and consequently this may lead to inaccurate decision-making.

Knowledge mapping is difficult when there is uncertainty in a supply network. Owing to its unpredictable nature, which complicates the process of knowledge mapping, it is necessary to extract the operational intelligence within a supply network so that the operational intelligence can be used as "clues" for predication on probable uncertainty. The review above shows little work on analysing "knowledge" with "intelligence". In this research, operational intelligence can be defined as a kind of integrated knowledge at a level higher than tacit knowledge on operations within a supply network. For example, the time for repairing a machine, which is not recorded and is a form of experience of the operator, can be deemed a type of tacit knowledge. Integrating this tacit knowledge to other related operations in a supply network, it may inform the decision maker that a probable delay due to machine breakdown can be minimised with the use of a different spare part. Thus, this operational intelligence activates an informed decision-making, which attempts to deal with uncertainty by integrating knowledge from other sources in a supply network.

To enable knowledge mapping, discovery of operational intelligence is necessary. Brooks (1991) noted that an intelligent system is decomposed into independent and parallel activity producers which all interface directly to the world through perception and action, rather than interface to each other particularly much. Business intelligence is also an important source of operational intelligence. Anon (2000) suggested that evolving applications will support a closed loop decision-making process whereby the output of business intelligence applications is routed to operational system users in the form of suggested actions which could be taken to remedy specific business problems.

Distributed intelligence has been proposed by Lüder and Peschke (2004) as a flexible approach for controlling plant automation. Human intelligence has been suggested by Zhou and Chuah (2000) as the key factor for successful intelligent manufacturing. These are possible sources of operational intelligence to assist knowledge mapping and uncertainty management.

Garavelli and Gorgoglione (2003) proposed a framework to analyse manufacturing problems according to a knowledge management perspective. The analysis is based on the main knowledge processes involved in problem solving, namely knowledge generation, memory, transfer and codification. Each can be assessed by variables such as uncertainty, space-dependence, time-dependence, and codification level, describing manufacturing problems in terms of, for instance, degree of coordination and integration, repetitiveness or uniqueness of the solution. Owing to multi-tiers of suppliers in a supply network, codification and knowledge sharing may not be straight forward.

This research proposes an approach for discovering operational intelligence and knowledge mapping in a supply network with uncertainty. The approach is developed by referring to the concept of new value stream or supply chain mapping (Hines and Rich, 1997) and by adapting the notion of using operational intelligence as "clues" for uncertainty management. It is envisaged that this approach will assist better decision-making.

3. Knowledge-mapping techniques

The knowledge embodied in managers' experience is tacit. Ideally, managers need a knowledge-mapping tool that gives them a way of eliciting and capturing this knowledge, a mechanism for retaining it and, if possible, a way of providing a comprehensive check. A typical output could be a formal explicit model of variable linkages, in contrast to their previous tacit mental models.

Once the variable linkages are understood, analysis is required to determine the potential impact of changes being considered. A knowledge-mapping tool that automates this analysis would allow managers to consider a wide range of options in a short time. The final stage, an evaluation of the options, requires the consideration of many factors, so some form of multi-attribute decision-making is required. A knowledge-mapping tool should provide the appropriate level of functionality and detail, yet be easy to use. In short, the requirements of a tool for knowledge mapping are (Tan and Platts, 2002):

- *Sequential decision-making*. Supports managers through the entire process from identifying relevant variables to evaluating decisions.

- *Visualization support.* Provides visualization support at each stage of the decision-making process.
- *Integrated documentation.* Captures information on variables and linkages for analysis or comparison.

3.1 Appraisal of existing techniques

When setting out on the task of knowledge mapping and operational intelligence gathering, managers have available to them several existing techniques to generate ideas, and structure and analyse problems. Could these techniques sufficiently help managers to identify a range of actions? In order for managers to generate a wide range of actions they need to identify the relevant variables within a problem situation, to develop an understanding of these variables and the linkages among them, to analyse these linkages and, hence, identify actions, tools and techniques that they can use. Finally, the alternatives need to be evaluated and an action plan to be compiled for further implementation.

Tan and Platts (2003) made a comparison of existing causal mapping techniques for knowledge mapping (Figure 1). They pointed out that the general purpose mapping tools described above could be used for the first part of this task. They provide a way of scoping a problem and identifying relevant variables. However, because they are general purpose, they are not necessarily optimized for the knowledge-mapping task. For example, cognitive mapping might result in overly complex models since it allows the development of multiple foci, whereas fishbone diagrams, created for specific problems with clear boundaries, might be too simplistic.

A range of commercially available software packages has been built around the techniques discussed above. These software tools (Figure 1) automate the application of the techniques and enhance information visualization. However, they generally address a specific stage of decision-making process and do not provide comprehensive support through all the stages. This work aims to provide managers with a software tool that supports their analysis at every stage of the decision-making process.

4. An "intelligence handbook" approach

Tan and Platts (2003) developed a software tool called TAPS. The tool is implemented under the Microsoft Windows operating system using Microsoft's Visual Basic 6.0 programming language. TAPS has four main modules:

(1) database;

(2) graphic user interface;

(3) algorithm; and

(4) evaluation.

They use a network diagram to represent the inter-relationship between a variable and its connected variables. In the network diagram the variable is displayed as a node with edges (lines) linking it to other nodes with which it has a connectance. Arrows connect variables to indicate the existence and direction of a connectance. Thus, a variable's connectance network is made up of nodes and relations.

Having studied and investigated the TAPS approach in details, we believe that it could be used as a tool to address the issues of knowledge-mapping and intelligence gathering in a supply network.

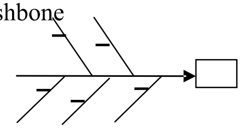
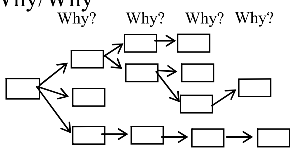
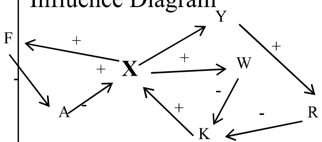
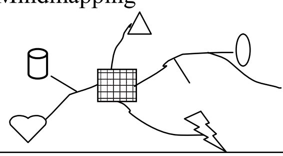
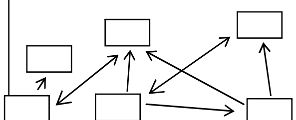
Mapping Techniques	Characteristics	Strengths	Weaknesses	Useful software
Fishbone 	Identifies root cause of a problem by breaking it down into its components	• Detail analysis on specific narrow problems	• Narrowly focused • Difficult to analyze if the diagram becomes too complex	SmartDraw
Why/Why 	Generates a hierarchy of causes and sub-causes by continually asking the question 'Why?	• Simple to apply, even verbally	• Tends to build a complex hierarchy as there is no boundary for asking the question 'Why'	Autocad; Microsoft Office
Influence Diagram 	Represents all causal relationships of a phenomenon in a manner that is non-ambiguous and probabilistic	• Quantitative analysis can be performed on the developed model	• May not be suitable to analyze complex problems which involve relationships that are qualitative in nature	Analytica
Mindmapping 	Images and keywords are used as an aid to memory and making intuitive associations	• Personalized diagrams are easy to recall and associate	• Mainly for education purposes	InfoMap
Cognitive Mapping 	Uses statements to build complex networks for a problem. Allows multiple foci.	• Easy to apply • Could build a network from any focus	• Could result in a very complex model • No structured approach for constructing a network	Decision Explorer

Figure 1.
Comparison of causal mapping techniques

A TAPS network diagram has five basic levels. The bottom level displays the objective or the variable on which analysis is to be carried out. At level two, the objective is broken down into its different dimensions. For example, "Increase flexibility" can be broken into four resource dimensions (Slack *et al.*, 1995): System flexibility, labour flexibility, process flexibility, and control flexibility. At level three, the relevant cause-effect variables for each dimension are displayed. The fourth level displays the actions that could be taken to address the variables. For example, the variables affecting labour flexibility could be training and working hours. One of the actions that could be taken to address "working hours" is overtime (Figure 2). At level five are tools that could be used to address particular actions or variables.

To enable a user to identify actions related to specific variables, TAPS has built-in functions called "trace-down" and "trace-up". Trace-down is an analysis to determine the effect of a given direction of change in one variable on other variables in the network. Trace-up analysis, starts with a desired direction of change in a variable and works back to find which other variables have to be changed in value and in which direction. These functions allow a user to perform an analysis on any variable in the network diagram. Please see Tan and Platts (2003) for further descriptions of TAPS functions.

4.1 Mapping operational intelligence

Tan and Platts (2002) argued that there is no single or best way of categorising management tools and techniques and categorisations will depend on the task at hand. For this task the main requirements are:

- *Comprehensiveness.* The handbook should cover all known techniques, tools and variables.
- *Linkages.* The handbook should indicate to managers the inter-relationships among tools, techniques and variables.
- *Visualisation.* The inter-relationship among tools, techniques and variables should be graphically illustrated.

Taking each of these in turn.

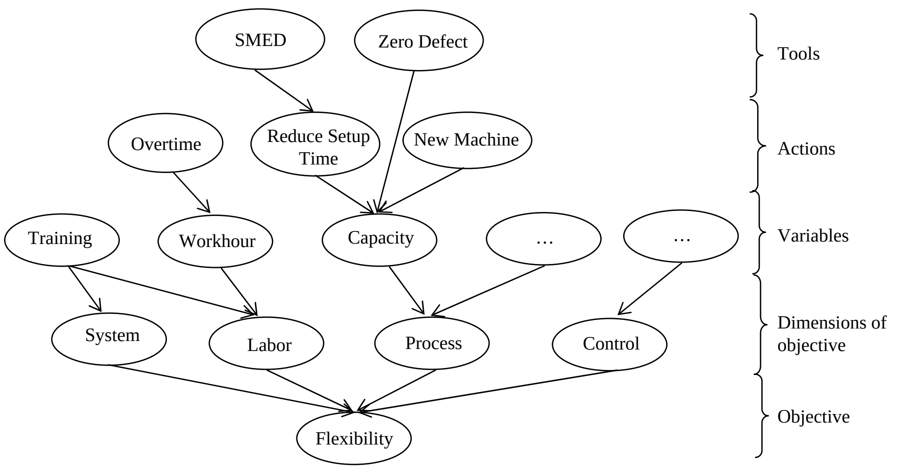


Figure 2. Structure of the network diagram for flexibility

- *Comprehensiveness*. Clearly it is unlikely that the handbook will include all known techniques. The intention is to allow managers to map out operational information and knowledge in a supply network.
- *Linkages*. The existence of inter-relationship among tools, techniques and variables can be shown graphically by placing the names of the tools, techniques or variables within circular nodes and connecting those two nodes with an arrow.
- *Visualisation*. The five basic levels of TAPS network shows the inter-relationship between tools, techniques and variables. By using the database functions, managers could codify the source of information from various partners in a supply network.

Figure 3 shows a structure of a handbook. Basically, for a given objective, the handbook could perform three main functions to:

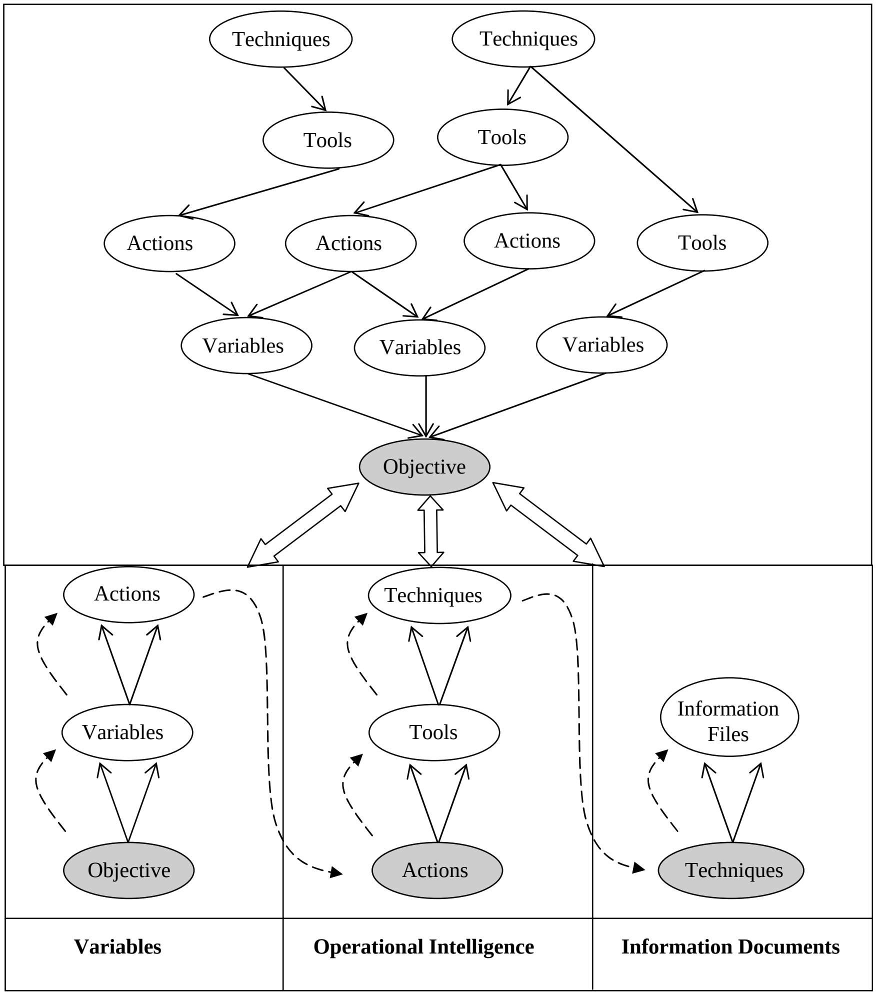


Figure 3.
Structure of the handbook

- provide an overall view of relevant variables;
- enable a more detailed view of the operational intelligence (actions, tools and techniques); and;
- provide information about each tool and technique[1].

We called the operational intelligence approach as Intelligence TAPS (iTAPS).

5. Application

Let us take a look at some examples to illustrate the application of iTAPS. If a manager wants to improve manufacturing flexibility, a trace-up analysis on the "process" dimension of a "flexibility" variable could be conducted. Figure 4 shows the network diagram for a "process" dimension of flexibility. At the upper level are the action plans (actions, tools and techniques). The network illustrates to managers the indirect impact of an action could have on a network.

Managers also could use iTAPS to identify suitable actions for managing the supply chain uncertainty. Its suitability is decided based on satisfactory on-time delivery performance achieved by certain cluster of enterprises. The identified alternative actions are then prioritised using the AHP built-in decision support feature of TAPS (Figure 5). Supply chain uncertainty that affects on-time delivery could be tackled via a number of different actions. For example, the possible actions (alternatives) include total preventive maintenance (TPM), training need analysis (TNA), and overall equipment efficiency (OEE) (Figure 6). Three criteria are used to assess the merits of the identified actions in achieving the objective of on-time delivery.

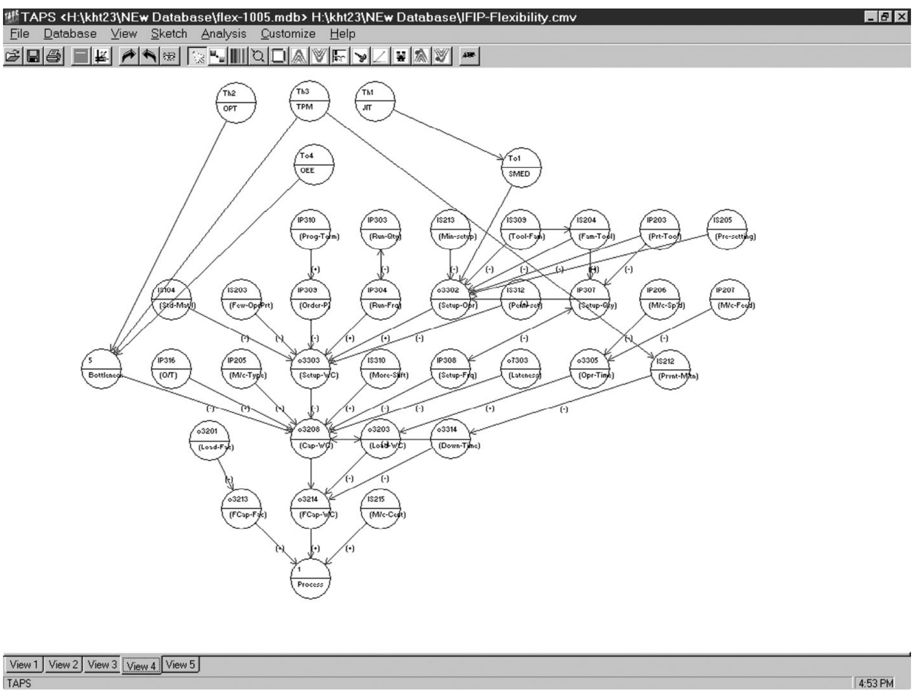


Figure 4.
Trace-Up network diagram for "process" dimension (partial view)

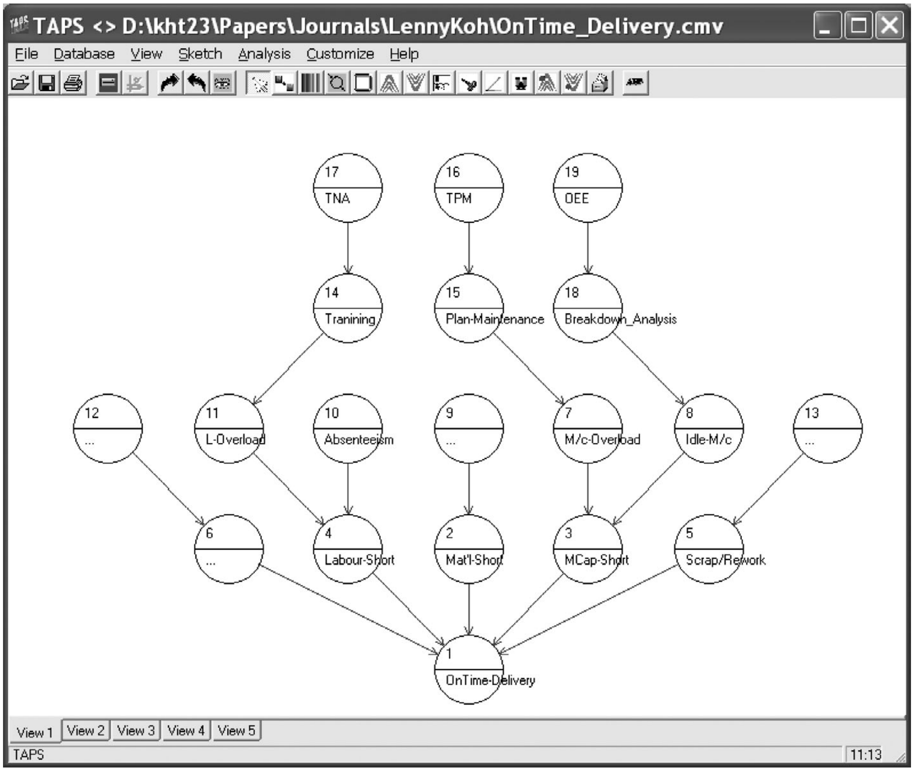


Figure 5.
A partial TAPS model

These include time effectiveness (time taken to provide results), sustainability (continuing for a long time), and integration (ability to integrate well with existing practices). In the above example, the results of the pair-wise comparison suggested that TNA has a major impact on time effectiveness, sustainability and integration. Therefore, TNA could be taken as an action to achieve on-time delivery.

6. Conclusions and implications

In this paper we have demonstrated iTAPS, an operational intelligence approach to managing supply chain uncertainty. In practise, iTAPS application is best done in a group. iTAPS provides clarity by facilitating communication among managers and helps to get everyone's view out in the open, where assumptions can be recognised and challenged and where the need for more detail information becomes more obvious. We believe iTAPS provides managers with following benefits:

- an ability to visualise the operational intelligence for a given objective; and
- an ability to identify the likely effects on implementing a particular tool or technique in a supply network.

In the longer view, iTAPS should facilitate the accumulation and integration of a body of production knowledge, so that what is learned through coping with one set of problems can be brought to bear on others.

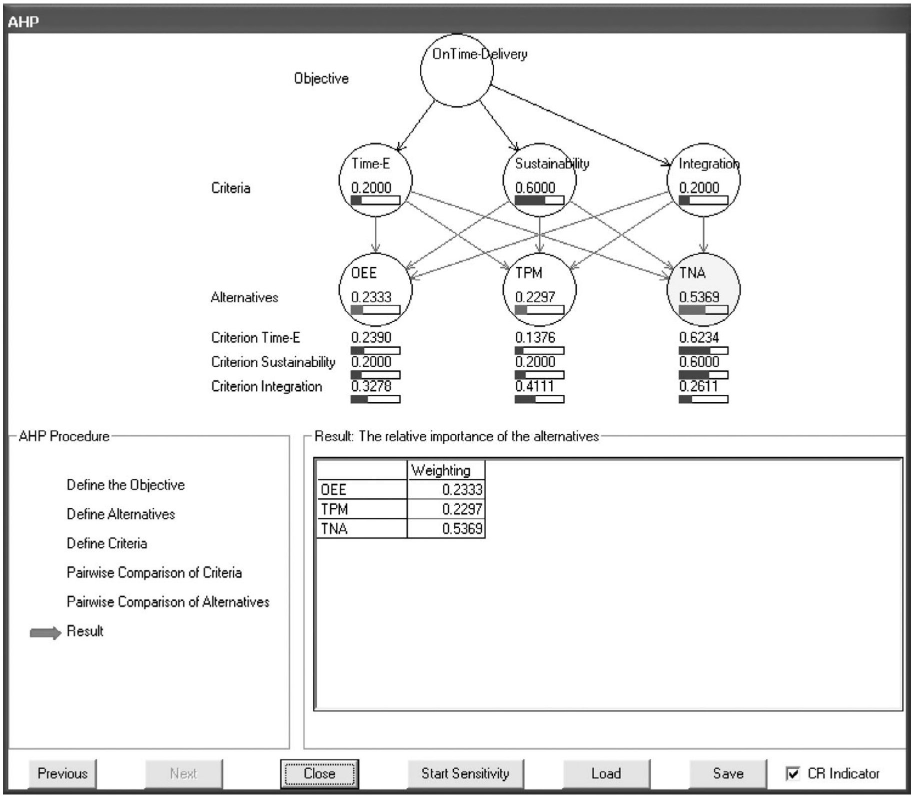


Figure 6.
Prioritisation of actions

Note

1. For the intelligence handbook approach, we categorised tools and techniques separately. Tools as ways to carry out a particular task, whereas techniques are programmes or procedures which comprise a set of tools (Tan and Platts, 2002).

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