Towards Better Approaches To Decision Support in Logistics Problems

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Abstract: This position paper outlines our current research to develop a decision support framework for logistics problems. The research covers methodologies, technologies and software tools. The framework considers typical characteristics of real-world logistics problems, common questions to consider in decision support and the technological capabilities to address these characteristics and questions. The proposed approach is analysed in the terms of potential benefits gained from better decision support in logistics problems.

1. Introduction and Motivation

Logistics is the process of managing the flow and storage of materials and information across the entire organisation with the aim to provide the best customer service in the shortest available time at the lowest cost. Long haul delivery, warehousing, fleet maintenance, distribution, inventory and order management are all examples of logistics problems. The world wide cost to industry of outsourced logistics problems in 1995 (maintenance of fleets, distribution and delivery of stock) is estimated to be AUS$ 900,000,000,000 (900 billion dollars) of which the cost to Australian organisations is two billion. Given the proliferation and complexity of some logistics problems the application of computer systems, particularly decision support systems to logistics problems is expected to increase significantly. Whilst any automation is useful (eg. order tracking/reporting and stock management) we believe that more profitable use of computing systems would result if the unique combination of characteristics that most logistics problems contain were considered. In our experience most real-world logistics problems combine the following six characteristics:

- Large Decision Space **-** Most logistics problems consist of a large number of decision variables and the possible options/strategies available to satisfy a problem are difficult to understand, evaluate and prioritize.

- Availability of real time data **-** Modern business operations usually have extensive data collection capabilities. This provides operational data which can be used for effective optimisation and communication of relevant information to appropriate decision makers in real-time.

- Uncertainty **-** Uncertainty is an inherent feature of most business environments. Decisions must often be made with uncertain and incomplete knowledge about future circumstances (e.g. order requirements, resource availability, yield characteristics). In addition, unexpected operational events within the execution environment (e.g. supply delays, breakdowns) need to be handled.

- Numerous decision makers **-** Logistics control and management typically involve multiple decision makers at different levels. It may include marketing, tactical, managerial, scheduling, operational, monitoring, supervision and control tasks.

- Complexity **-** Logistics problems consist of numerous components characterised by their dynamic behaviour and high interconnectivity. Understanding the dynamics of such problems and solving them is usually difficult.

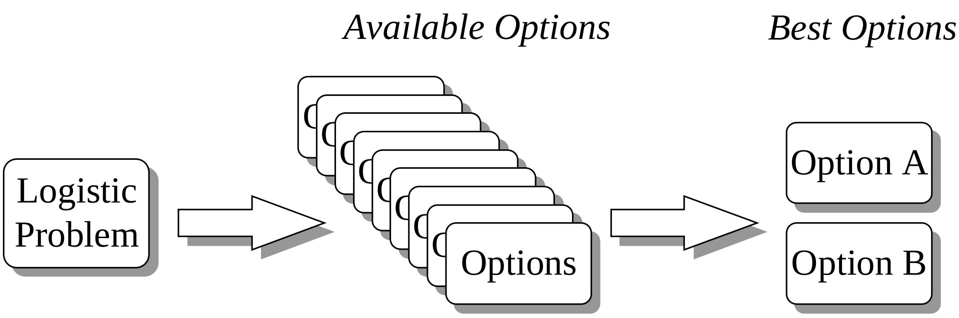
- Highly Constrained **-** Production and business processes are driven by a diverse and often contradictory set of constraints ranging from production objectives (e.g. efficiency, quality, profitability) to physical constraints (e.g. resource capabilities, utilisation requirements, operating preferences).

Current software tools for decision support in logistics do not totally address the combination of these characteristics. Software developed specifically for logistics problems are usually of the reporting and tracking variety and/or automate routine tasks but offer little support for decision making. Tools currently available for decision support are usually problem specific or too general to complement the decision process in logistics problems.

We view that most logistics problems have many potential options/strategies to handle them. These options can be in the form of plans, decision sequences or courses of action. Each option can be ranked with respect to some objective such as robustness (minimum risk) or cost effectiveness.

Each of the previously mentioned characteristics raises important issues and questions. Our research plan summarises them into eight important questions (shown in figure 1) for the decision maker. Most tools address to some degree the first five questions. Tracking and reporting tools address primarily questions one and three whilst optimising and decision support tools focus on questions one through five particularly three and five. No or few tools consider questions six, seven and eight. Addressing these remaining questions would provide additional information which are important for decision making. Question six encompasses explaining why the "best" option was selected and which components (eg. constraints and optimiser) influenced its selection greatest. Question seven considers how to summarise of the key characteristics of an option, whilst question nine considers how to summarise the implications/risks that would occur if this option was implemented.

Our research attempts to address all the eight questions which are important for decision makers in one framework.



1. How to express/represent problem ?
2. What are the options available ?
3. How to characterise/rank options ?
4. What are the best options ?
5. Which option to select ?
6. Why the option was suggested ?
7. What information the option contains ?
8. What are the consequences of this option ?

Figure 1: Questions the Proposed Decision Support Framework will Consider.

2. Methodology

To address all the questions we have raised in the previous section we have divided our research into several complementary areas as follows.

- *Constraint Handling.* Most real-world logistics problems are highly constrained in a variety of complex ways. Constraints can range from hard constraints that must always be satisfied (e.g. equipment limits, precedence, physical properties, legal regulations) to soft constraints that can be relaxed in some circumstances (e.g. costs, due dates, preferences, resources, decision rules). Constraints are often dynamic (e.g. changing over time or valid only in specific situations) and may sometimes be contradictory (e.g. competing objectives such as cost and quality). Modeling of the uncertainty of the environment (e.g. equipment breakdown) and the problem description (e.g. due date is sometime next month) must be considered. Representation, management and satisfaction of soft and hard constraints defined in a complex and dynamic environment are the key research issues.

- *Constrained Optimization.* Solving highly constrained logistics optimization problems has always been a challenging task, especially in the presence of nonlinear, implicit or disjunctive constraints. However, constraints may also be used to support and guide optimization based on intelligent search methods. These methods usually search for an acceptable near optimal option (or a set of options) rather then the optimal option. We will explore these to support flexibility and efficiency of heuristic optimization.

- *Robust or Minimum Risk Solutions.* Most real-world logistics systems typically operate in an uncertain and changing environment. Decisions that are optimal (acceptable) in given circumstances may become considerably sub-optimal if the situation changes or the behavior of some aspect of the environment is not as expected. For example an efficient delivery schedule may become considerably inefficient if disturbances (e.g. vehicle breakdown) happen. Our research will focus on generating solutions which are still “optimal” even when environmental changes occur.

- *Dynamic Re-solving/Rescheduling.* Solutions in real-world situations may require quick re-solving (e.g. rescheduling in scheduling problems) due to unforeseen significant changes in the environment, user’s decisions or problem requirements. For example, dynamic production rescheduling could be necessary when a significant number of new urgent orders arrive.

- *Solution Explanation.* Specifying why a particular solution has been reached offers many benefits to the user. In particular, understanding how the constraints, optimiser and user’s decision interact to produce the final solution allows the user to change a component to improve results.

- *Knowledge Extraction from Solutions.* The solutions to decision-making problems (especially constrained problems) usually contain a rich amount of information which due to its detail is often not completely understood. Extracting out key features, patterns and characteristics of the solution should improve understanding and implication.

Some of the above research issues are dependent and rely on each other. The inter-relationship between the issues, which can also be interpreted as a general decision support system framework, is illustrated on figure 2 below.

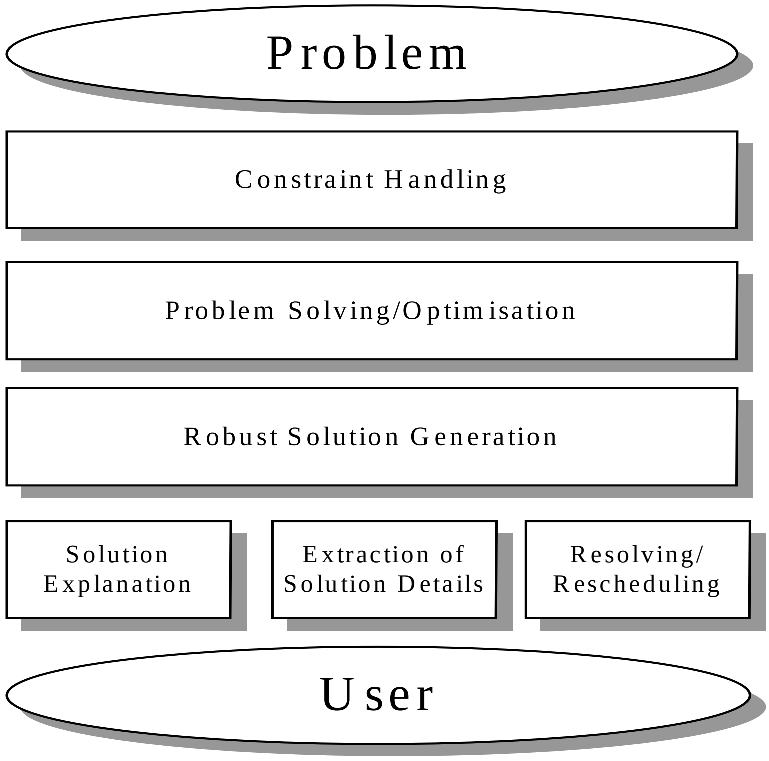


Figure 2: A General Decision Support System Framework For Logistics

Table 1 provides a mapping between research areas and logistics problem characteristics considered in our research.

	Large Decision Space	Complexity	Highly Constrained	Uncertaint y	R/T Data Utilisation	Multiple Decision Points
Constraint Handling	✓	✓	✓	✓		
Constrained Optimisation	✓	✓	✓		✓	
Robust Solutions	✓	✓		✓		✓
Dynamic Re-solving		✓	✓	✓	✓	✓
Solution Explanation	✓	✓	✓			✓
Knowledge Extraction	✓	✓				

Table 1: Matrix of Research Area Most Relevant to Logistics Problem Characteristic

3. Technology and Capabilities

Due to the complex nature of the research issues outlined above, it is anticipated that a combination of different and complementary artificial intelligence (AI)-based techniques should be used to address them properly. These techniques include the following:

- *Approximate Reasoning* is a technique to support decision making in the presence of uncertain, incomplete and imprecise data, information and knowledge. Fuzzy logic is a technology commonly used in approximate reasoning. Its unique feature is the ability to represent and reason about both quantitative data and qualitative (linguistic) knowledge simultaneously (e.g. if due date is the 10th and order priority is high then start job around 9am today). Approximate reasoning (fuzzy logic in particular) is relevant to the issues of flexible constraint handling and robust solutions.

- *Constraint-based Reasoning* is a technique to support constraint handling and solving constrained problems with the use of the principles of constraint satisfaction and propagation. The main strength of constraint based reasoning is the ability to represent problems in the terms of constraints and reason directly in the problem domain (e.g. all time and resource requirements and preferences in scheduling can be expressed directly using constraints which leads to a natural problem representation and solution). The ability to represent and reason about constraints makes constraint logic reasoning relevant in the context of the decision support to provide a number of options and determine why an option was chosen. Research issues include constraint handling, constrained optimisation, robust solutions, dynamic rescheduling and solution explanation.

- *Heuristic Optimisation* is based on the use of heuristic algorithms to solve optimisation, especially combinatorial optimisation problems. The heuristic algorithms can be either problem specific or generally applicable. Problem specific heuristics are very narrow in their application since they exploit information about the problem at hand to ease the search. Generally applicable algorithms are much more general in their applications and can be applied, with only very minor changes, to a wide spectrum of problem types. Examples of such algorithms are heuristic search, simulated annealing and evolutionary algorithms. Generally applicable heuristic algorithms are relevant to the issues of constrained optimisation, robust solutions, and dynamic rescheduling. Incorporating flexible and efficient constraint handling methods into heuristic optimisation would be the initial research focus.

- *Learning by Induction* is a process which draw generalisations from limited information. An inductive process searches data for regularities and patterns. This helps to simplify understanding of a collection of data by summarising it into the form of rules, taxonomies or classes/groups for instance. This can be used to explore the information contained in options (decision strategies for instance) and to summarise them. The optimisation process used to find the best option can be analysed to determine what influences (constraints for example) resulted in the decision.

4. Potential Benefits

It is believed that our approach to decision support in logistics problems can bring substantial benefits in real world situations. The authors have worked on numerous practical problems in the past, where if approaches to the proposed framework of questions were available, would have provide additional benefits. These projects have provided the motivation and impetus for our current research directions.

As an example of the potential benefits of this framework, we will describe how a previous project worked on (spatial layout of a hospital) would have benefited. The work completed three years ago was successful. However additional benefits could have been realised with the use of the proposed research.

The hospital layout problem encompasses how to best place activity centres (casualty and psychiatric wards, operating theatres, nurse supply centres, laundry supply centres and kitchens for instance) within a building (which may or may not have been designed) to minimise the time spent by doctors, nurses and other staff walking between their various duties through the day. This in turn minimised a large proportion of the operating cost of the facility. The problem can be viewed as distribution and movement of supplies and attention to patients.

This problem fits our description of a logistics problem and has the characteristics previously mentioned. The possible number of building designs and layouts was *n!* where *n* is the number of activities which in initial studies was one thousand (large decision space). There was a stochastic aspect associated with staff movement given staff did not always move in set ways every day or were absent (uncertainty). Minimising operational costs was not the only concern. Architects wished to have an aesthetically pleasing building and operation management wished to have sensible activity placement, psychiatric wards being isolated for instance (numerous decision makers). The hospital was a large collection of staff members each moving between various activities through the day to meet their requirements (complexity). The limitations on the design was significant, wards had to be rectangular instead of linear, casualty had to be easily accessible and various other constraints on position and interaction of activities existed (highly constrained).

The input to the layout optimising system developed (TOPMET++) included the building grid envelope dimension, size of minimum module, activities to layout, interaction between activities, salaries of staff and so forth. The output of the process was a large amount of information containing the layout of the hospital specifying which activities would occupy specific positions (including floor location) and the best building shape. The expected operational costs was also calculated.

Whilst the study was successful our planned research, if available, would have offered significant improvements. Modeling the restrictions on layout limitations (eg. lift movement, walking rates, preferential placement) was difficult and required considerable time to make alterations. Placing biases to appease the multiple decision makers would have also benefited given their demands were strong recommendations rather than physical limitations. Using a constraint handling approach would have allowed a more viable modeling of the constraints. Producing a solution which could handle uncertain and changing environments would minimise the risk of not being able to complete all the required staff activities.

However, the largest benefit would be in the solution explanation and extraction stages. The information provided as the solution was volumous without sufficient explanation why it was reached nor what it meant. Extremely time consuming manual investigation answered these questions in the original study. Our proposed research would provide insight into what constraints or problem definition aspect most influenced the solution. This would be useful to determine how to make changes to produce a better working hospital. The knowledge extraction research area would allow the hospital layout to be summarised this would help in conveying the design to the various people involved.

The above is a specific example of benefits. In general the decision support framework could contribute to:

- Substantial cost reductions of logistics services arising from higher quality decision support and making in management and control tasks specific to highly complex and dynamic business environments.

- Increased productivity and quality arising from the adoption of new technology and improvement strategies in logistics management and control.

- Adding support for specific characteristics of logistics problem such as risk minimisation.

- Improved flexibility, market responsiveness and service quality arising from the application of flexible and adaptive decision support tools.

- Software products and value-added services.

5. Future Work and Conclusion

Recently the authors have been involved in various logistics projects such as scheduling, layout, process optimisation, planning, distribution and dispatching. We envision that some components of this research will be incorporated into future stages of some of these projects. Our plan is to develop general techniques to handle each of the various problems we have described by focusing initially on the generalised assignment problem which we believe can be adapted to represent a large proportion of logistics problems and their characteristics. When specific projects arise the techniques will be customised and applied to them.

We believe that this work can provide much needed support for handling complex logistics problems by specifically addressing their requirements.

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