Radical
GLOBAL STRATEGIC LOGISTICS MODELLING

Modelling Approaches

Heuristic and Mixed Integer Programming Optimisation

With the release of CAST-2002, Radical has decided to integrate the MIPO, Mixed Integer Programming Optimisation module within the core CAST product. Previously the optimiser had only been available for purchase as an additional module. The inclusion of this module is not only for new clients purchasing CAST, but also for all our existing customers. This further demonstrates Radical's goal to make users more productive and offer good value for money.

This section looks at the definitions of these two approaches, their relative benefits and differences, together with the circumstances where one might be used in the place of another.

Definition - Heuristic

By way of introduction the terminology 'heuristic' and 'mixed integer programming optimiser' has already been used. It is important that we understand what is meant by these terms and how the two approaches may be used when running supply chain models.

The Heuristic Approach

The 'heuristic' approach is the method that CAST has employed to evaluate network modelling issues since 1989.

'Heuristic' literally means by 'trial and error'. Most of us do not like the concept of 'error'; a moderated definition is to say that you can find a solution by employing a 'what if' approach to network modelling.

We all use heuristic techniques in our everyday lives to solve problems using 'rule of thumb' approaches. We apply our heuristic judgement in many situations. For example, completing a jigsaw puzzle. We try alternative pieces in combination until we find pieces that fit together. We often shortcut the puzzle building process by finding all the edge pieces first to build a frame for our solution, once again this is a heuristic approach. We all know that this process works very well and teach children to do it when they play with jigsaw puzzles.

In other instances where we use heuristic estimating in our daily lives we find our estimates are more often than not accurate. That is not to say that sometimes the technique might not work for us but we accept its limitations and then take an appropriate course of action to deal with the shortfalls of our heuristic estimates as and when they arise.

Within the context of 'Supply Chain Modelling' using CAST, the heuristic modelling approach involves the generation of a series of models that are run against CAST's cost minimising heuristic algorithms.

Each model consists of a user defined network configuration. For each network configuration, subject to any constraints or parameters, CAST minimises network resource costs. By running a series of models, the cost outputs of each may be

compared to find the network configuration that meets the requirements of any individual project scope and objectives.

This means that the 'heuristic' modelling approach is necessarily iterative. In the same way that we try fitting pieces of a jigsaw puzzle together in combination until we find the arrangement of the pieces that ultimately completes the picture.

In the same way for our heuristic network optimisation, CAST models are run over and over again against different network configurations to find the network configuration that satisfies the scope and objective for any given project.

Definition – Mixed Integer Programming Optimisation

Mixed integer programming optimisation is a mathematical technique used to make resource allocation decisions where there are competing demands upon resource and overriding criteria to be satisfied. The primary criterion that is most often prevalent is cost minimising.

Given that MIPO is a mathematical technique from the branch of mathematics called 'operations research', it is difficult to explain the detail without introducing mathematic terms with which most of us are not instantly familiar.

Returning to the jigsaw analogy, the optimiser can be considered as being a method that tries to fit every piece with every other piece subject to a set of constraints, like edges, lugs, colour etc.

A significant difference is that the optimiser is not iterative; it is run once to deliver a solution. The technique itself uses a combination of:

Linear programming - Sets the variables and constraints of a solution within a continuum. This means that a variable or constraint can be any number including a decimal constituent between zero and infinity.

Integer programming – Sets the variables that can be considered as either on or off. For instance warehouses in a model are either available, 'on' or not available, 'off' and are therefore represented by whole numbers with no decimal. This type of number is known as an integer.

We can look at a combination of integer and linear constraints when considering a warehouse. In terms of the warehouse itself it can either be on or off, included or excluded from the solution, however if it is included its throughput is a linear variable which can be set at any value between a minimum or maximum throughput. The warehouse throughput does not necessarily have to be an integer value.

Definition – Optimisation

Within the scope of the computer hardware, operating systems, software technology and mathematical techniques that we can practically employ there is no such thing as 'true' optimisation. At the risk of employing mathematical jargon, mixed integer programming optimisation is what is known as 'NP-hard'. This means the number of potential combinations that can be put together to solve a problem make finding 'true' optimisation very difficult to establish. The good news is that the variation between 'true' optimisation and reasonable optimisation may be so small that the exertion required to find 'true'

optimisation is not worth the effort. We have already established that finding a result heuristically by definition is never classed as being truly optimal because of the nature of the approach. Yet the results delivered are, in nearly all circumstances, sufficiently acceptable that they can be considered a 'practical' form of 'optimisation' given the currently imperfect situation.

Even with the MIPO approach optimisation is a concession between the compromises made when defining a 'real world' configuration in mathematical terms, the time we are willing to wait to calculate a solution and the capabilities of computer hardware principally in terms of RAM memory and processor speed.

In the context of supply chain modelling the mixed integer programming optimiser allows a mathematically optimal network configuration to be found given a user defined set of candidate locations subject to any constraints or parameter settings.

Which Approach is Best – Heuristic?

The benefits of the heuristic modelling approach are derived from the user's interaction with the model using their own logistics knowledge and computing skills in combination with the cost minimising heuristic algorithms.

By running a series of CAST heuristic models called 'strategy models', the user gets to know the sensitivities, trade-offs and dynamics within a particular supply chain network thus enabling very practical solutions to be delivered. The solution that is delivered may be considered more of a 'preferred solution' rather than a mathematically optimal solution. The very hands-on approach does however mean that the 'preferred solution' is practical to implement.

Inherently this is an iterative approach so many models have to be run and evaluated as part of the process. This requires significant user intervention to construct manually and iterate run-by-run the models required.

Software features like 'batch processing strategies' for given 'selected strategy run definitions' alongside the histograms and tabular outputs from the 'compare strategy results' make the iterative nature of this type of modelling more user friendly than the manual comparison of results.

Given the heuristic does not work to a set of mathematical rules it is not possible to gauge the quality of the solution relative to a theoretical optimum.

A full cycle of evaluation of many options has to be considered before the heuristic planning phase is complete. Unlike an optimiser the process cannot be terminated early and at the same time establish the best result at the point at which the process is curtailed.

Which Approach is Best - Mixed Integer Programming Optimisation?

The mixed integer programming optimiser allows a mathematically optimal least cost network configuration to be found given a user defined set of candidate resource settings subject to any constraints or parameter settings.

The optimiser is run once but depending upon the size and complexity of the supply chain network being modelled may take some time to run. This approach requires less

user intervention than the heuristic method once the problem to be solved has been defined.

To counteract long run times, CAST has a new feature whereby the convergence of what is known as the 'unbound solution' to the 'bound solution' can be plotted to show progress towards finding the optimal solution. This gap can be measured to assess the gap between the delivered solution and the best possible solution

The user is able to terminate the model once significant convergence is achieved in order to return the best solution at this point to save extending the run time, which may only produce an insignificantly better result.

The output from the optimisation process may deliver a perfectly intuitive supply chain network configuration. In other instances it may not. Where counter intuitive outputs are encountered due to the 'black box' nature of the mathematics, it is possible to use the result within the heuristic modelling approach to refine the outcome to evaluate a more practical approach to the delivery of a network solution.

Optimisation is very good way to benchmark either an existing or heuristically generated network configuration against the optimum. It can be used as a starting point for further heuristic evaluation or as a direct measure against current practices.

Guidelines for selecting which approach to use?

There are no absolute guidelines for suggesting where and when it is appropriate to use the heuristic versus the mixed integer programming optimiser approach. As a guide, the following points have been put together around each option:

Firstly the heuristic approach:

- Where a very practical solution is required.
- Where a preferred rather than 'optimal' solution is acceptable.
- Where the user wants direct 'hands-on' involvement in the formulation of the solution.
- Where time is available to run and evaluate many iterations.
- Where it is important to understand the sensitivities, dynamics and trade-offs in a network.
- Where it is important to be able to defend logically one network configuration against another.
- Where the process is not going to be cut short and a solution still be expected.

Secondly the mixed integer programming optimiser approach:

- Where the near absolute mathematical least cost optimisation is the required output.
- Where time to run and manage many iterations is limited.

- Where the desire to run and evaluate many models is not prevalent.
- Where little or no user intervention is required outside the initial model set-up.
- Where it is important to measure the result against the absolute optimum.
- Where, if required, the process can be terminated and the best solution found to date can be delivered.
- Where it is accepted that the optimal solution may not be intuitive and further work may be required to evaluate a practical interpretation of the optimiser result.
- Where it is a requirement to measure existing or heuristically generated network configurations against an absolute optimum.

A combined approach:

- Whilst users will make their choice of approach depending upon the requirements of any one project, a combined approach may support either heuristic or optimisation as a secondary point of reference.
- If the heuristic is run first, then the optimiser, this allows the user to benchmark the heuristic 'preferred' solution vis-à-vis the optimum in a quantifiable way.
- If the optimiser is run first, then the heuristic, this allows the optimum solution to be modified according to the practical requirements for implementation.
- Whichever approach is selected the user can obtain significant benefits by using CAST to 'optimise' supply chain network infrastructure.

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