Redesigning Toyota's spare parts supply chain using tabu search

Kenneth Sörensen and Patrick Schittekat
University of Antwerp, Faculty of Applied Economics
kenneth.sorensen@ua.ac.be, patrick.schittekat@ua.ac.be

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In Schittekat and Sörensen (2009) we describe the development of a tabu-search based software tool to support tactical decision-making in the spare parts supply chain of Toyota Europe. For the distribution of spare parts to car dealers in Europe, Toyota operates two hubs, one in Germany and one in the Czech Republic. Car dealers requiring spare parts may place an order by telephone or the internet during the day and Toyota promises next-day delivery from one of its hubs for all parts ordered before a certain cut-off time. Such orders generate a complex workflow, in which the parts are first picked and readied for transportation. Then, they are combined into full truckloads (FTL) and transported to an intermediate *transport platform*, i.e. a warehouse or depot with some limited handling facilities. An important aspect of this supply chain is that all transport platforms are owned and operated by a 3PL (third-party logistics) provider, and that no inventory is held there. At the various transport platforms, spare parts are sorted and loaded onto (smaller) trucks and delivered to the car dealers the same night.

One of the most important problems faced by Toyota is the *selection of 3PL providers and their corresponding transport platforms*. To this end the company tenders a large number of potential 3PL partners, some of which it has not worked with yet. The 3PL providers then bid on a part of the distribution of spare parts, e.g. one or two regions in Germany. Based on these bids, Toyota selects the 3PL providers to work with in an iterative process of evaluation and negotiation.

The difficulty of this selection process stems from a number of factors. First, it is very difficult to gain insight into the cost structure of a 3PL provider, which gives Toyota a disadvantage in the negotiation process. Secondly, there is considerable uncertainty with respect to certain factors like the service level that is obtained by some logistics providers, and that often does not correspond to the quoted or required service level. Thirdly, the quality of a 3PL partner with which the company has a steady relationship, often has a tendency decrease over time. If Toyota decides to stop working with a 3PL partner, it needs an alternative supply chain configuration. Finally, the complexity of the real-life logistics network underlying the 3PL partner selection process, makes accurately calculating the total network cost very difficult without accounting for significant operational detail. Ignoring such issues as time windows, vehicle types, capacities and size limitations, as well as road network issues would result in poorer decisions as a result of poorly calculated costs.

The tool developed in Schittekat and Sörensen (2009) for the design of a transport network, i.e. the selection of 3PL providers is especially designed to overcome the difficulties mentioned above. The problem solved by our tool consists of two sub-problems that are solved simultaneously: (1) selecting 3PL providers and associated transport platforms to use and (2) determining milk runs to visit the car dealers from the selected transport platforms. Such a problem is known in the literature as a location–routing problem. In our solution approach, the location part is solved by a tabu search heuristic, whereas the routing part is left to a commercial solver software.

The innovation of our tool is twofold. First, rather than a single "best" solution, our tool generates a set of structurally different high-quality solutions. To this end, it uses tabu search to find good solutions and the Hamming distance metric to ensure that solutions are sufficiently different before storing them in an archive. Generating structurally different solutions offers insight into the different feasible transport networks, and allows the company to switch more easily and knowledgeably between transport networks in case unexpected events occur.

A second innovative feature of our tool is to solve the routing problem as a part of the transport platform selection problem. The tabu search algorithm guides the solution by making use of a commercial vehicle routing solver to generate heuristic solutions to sub-problems posed by the TS method. The guidance process produces the control parameters that determine the structure of the current routing problem, and then integrates the information from the heuristic solution to the sub-problem into the larger solution framework, while also incorporating this information into the TS system for updating the control parameters. The tool therefore effectively uses the embedded vehicle routing procedure as a means to generate "moves" within the TS method, implicitly identifying a neighborhood for the sub-problem and determining a next trial solution in the neighborhood. In our design we were additionally able to take advantage of the fact that the commercial solver addresses many useful features of the routing portion of the problem and includes valuable tools for visualization and mapping.

Since the final distribution of spare parts to the car dealers is outsourced to the 3PL providers Toyota in principle does not have to determine the customer scheduling and routing. However, by determining an optimal operational execution of the transport operations the company is able to gain a much more thorough understanding of the network design problem it faces. This in turn results in a better negotiating position with respect to (potential) 3PL partners, since the tool provides Toyota with a very accurate estimate of the distribution cost of their 3PL partners, which results in a deeper insight into how the 3PL partners make their decisions. Large deviations between these cost estimations and the prices quoted by the 3PL partners are subject to investigation and negotiation.

The tabu search based search method developed in our tool was implemented and tested in cooperation with the planning department of Toyota's European parts distribution centre in Diest, Belgium in a pilot test phase that took approximately one and a half years (August '05 to January '07) to complete. From January 2007 on, the tool has been in production and is currently used to determine the transport network for the distribution of spare parts in Germany. One person is dedicated to this task. The exercise is repeated at least once every month, depending on business needs.

The tabu search tool offers another feature that the company finds especially valuable. In addition to recording the best solution found, the tool also archives other viable solutions encountered during the search. Often it is not possible for management to express all its goals and key concerns in a formal optimization model. Moreover, company officials may not always be aware of all of these concerns until confronted with a range of possible solutions to their model. Consequently, by providing an archive of viable solutions, the tool enables the company to profit by studying these solutions in relation to current operations and by exploring implications that may be external to the model. This presents an opportunity to uncover potentially productive modifications such as switching dealers or entire milk runs to other transport platforms, shifting supply of a transport platform from one hub to another, eliminating transport platforms altogether, etc.

As an example, Toyota recently decided to close a transport platform near the city of Hanover in the north of Germany. Toyota was convinced that closing this expensive platform would cause a drop in service levels. Detailed analysis showed that dealers previously assigned to the closed platform could be integrated in routes starting from other —less expensive— nearby platforms. In practice, this decision turned out to be extremely lucrative.

Toyota also uses the tool to analyze alternative distribution strategies. In this way, it was demonstrated that direct milk runs from the hubs (without cross docking at a transport platform) are in fact an interesting alternative. Today, Toyota has these kinds of direct milk runs in place at both hubs.

Toyota reports that using the tool has resulted in a significantly lower total network cost. As generally occurs in problems of this scope and complexity, the exact cost savings are difficult to quantify. This stems in the present case from the fact that the total distribution cost is a complex aggregate, influenced by invoicing and price setting methods, negotiated tariffs and discounts in different countries with different taxation methods. Nevertheless, the flexible cost calculation method of the commercial vehicle routing software, using a different cost structure per vehicle type, is able to approximate the actual total distribution cost with an acceptable degree of accuracy and thus to yield hard figures that support Toyoda's evaluation that the tool produces a significantly improved total network cost.

Finally, Toyota company officials were also impressed by the advantages of combining the location and routing decisions into a single decision making tool and have stated that "The practical validation of the results generated by this method are strongly facilitated by the use of a very realistic vehicle routing model."

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References

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