2011 International Conference on Transportation, Mechanical, and Electrical Engineering (TMEE)
December 16-18, Changchun, China

Research on agent-based approaches to freight transport scheduling

Zhang Shuxin
College of Traffic, Jilin University
Changchun, China
e-mail: shx.zhang@hotmail.com

Jia Hongfei
College of Traffic, Jilin University
ChangChun, China
e-mail: jiahf@jlu.edu.cn

***Abstract*—In the last few years, the agent and agent-based technology have been researched and applied in a number of domains. However, the advantages and effectiveness are still under testing on freight transport scheduling. The aim of this paper is to examine the potential applicability of the agent-based technology to freight transport. The research started with literatures review, a real world experiment was then conducted by using an agent-based scheduling tool developed by Magenta. Two scenarios were tested in the experiments and the results were analyzed and evaluated by comparing with the actual operational performance. The results of the simple scenario were as good as the actual performance, while the complex scenario improved a lot. It is concluded from the study that there is an increasing trend and a number of positive aspects of the application of agent-based technology to the freight transport scheduling, the agent-based technology is suitable for solving the distributed, complex and volatile scheduling problems in the freight transport domain.**

Keywords- freight transport scheduling, agent-based approaches, experiment, performance

I. INTRODUCTION

The freight transport sectors across the UK and Europe are under increasing pressure from congestion, cost increases in fuel, environmental regulation, lack of driver resources and simultaneously fierce competition. Transportation companies are living on a fine margin and their customers are concerned about the sustainability of their economics and the risks of service disruption.

Most of the existing routing and scheduling approaches are deterministic and static, anchored by set scheduling concepts, and which fail in the face of delays, congestion, last minute order changes, etc. Real world freight transport operations are however dynamic and volatile, as such models used for routing and scheduling should be able to deal with these characteristics.

II. LITERATURES REVIEW

During the last few years, agents and agent-based approach have attracted a significant amount of attentions from researchers in freight transport and logistics. Agent-based approaches have been adopted for fleet scheduling, transportation network planning, logistics process management, transport modeling and simulation, etc[1]. Espcially transport scheduling and modeling are the hottest domain with agent-based approaches. Due to the dynamic, flexible and uncertain attributes of the information and its geographical availability, in the domain of transport scheduling and modeling, the agent-based technology shows apparent advantages. Currently, in most of the cases, the resources and information concentrated to a single central point when planning and re-planning is implemented [2]. Sawamoto proposed a multi-agent approach for handling the truck scheduling and routing problem[3]. To achieve real time scheduling, Mes introduced a method in which intelligent vehicle agents plan their own routes[4]. The agent-based transportation scheduling has been used in military logistics in Australia[5].

These researches and applications use agent-based technology or approaches, either as metaphor for modeling, software tool design or as an abstraction for systems development. The arrivals of agent-based solutions now provide that potential but have not been extensively applied in the road transport arena.

III. EXPERIMENTS

A. Background

Manor Bakeries is the branded cake business within Premier Foods, one of the largest food companies in UK and Ireland. Manor Bakeries produces cakes, tarts and cake bars including well know brands such as Mr. Kipling. The transportation planning and operation at Manor Bakeries is outsourced and operated by the Lloyd Fraser Group. In this research, Manor Bakeries' transport scheduling practice was adopted as the base case.

The operation of Manor Bakeries' transport includes deliveries and collections from bakeries, cold stores, NDC and customers. Manor Bakeries operates three bakeries, located at Carlton, Moreton, Stoke and a National Distribution Centre in Rugby. With the exception of the three bakeries and the NDC, three freezers and a total of 119 customer specific delivery locations are included in the logistics network The transportation fleet includes more than 60 trunks and 150 trailers. On average, about 500 customer deliveries are made every week, 15,000 pallet movements each week, and over 100 members of staff are involved in the management and operation.

978-1-4577-1701-7/11/$26.00 ©2011 IEEE

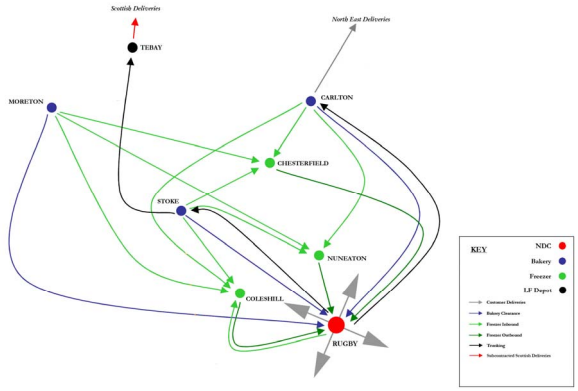

Figure 1. The transport movement of Manor Bakeries

Figure 1 outlines in detail the density of customer deliveries by geographic region. Key hotspots are primarily around major conurbations as would be expected: London, the North West and the Midlands.The detailed transportation network location is as follows:

- Three Bakeries: Carlton; Moreton; Stoke
- One NDC: Rugby
- Nine Freezer Locations: Chesterfield; Coleshill; Nuneaton; Wolveshampton; Chiltern; Liverpool; Whitchurch; Tewksbury; Peterborough

Currently, Manor Bakeries' transport schedule is planned manually based on experience. The planners use a bus stop plan (template), where 90% of the transport routes and times are the same each week, however the volume does change.The figure 2 illustrates the manual scheduling porcess of of Manor Bakeries.

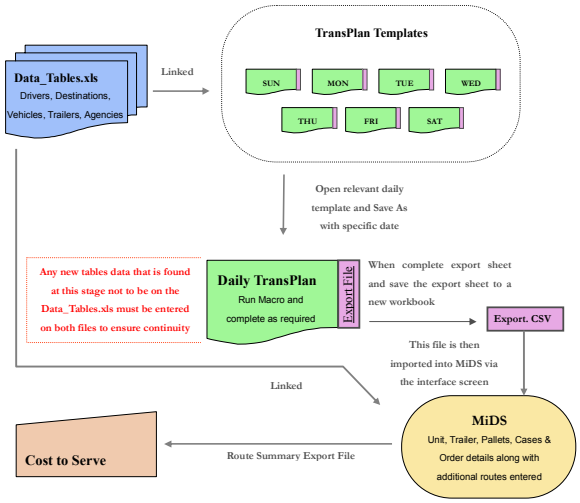

Figure 2. The transport planning process of Manor Bakeries

B. *Review of i-Scheduler*

Magenta's i-Scheduler is a software tool which provides continuous and complex scheduling based on an agent-based approach. It has been successfully deployed for tanker scheduling, however, in the road transport domain, the advantages and effectiveness are still under testing. The key purpose of this paper is to assess the potential application of agent-based technology to road freight transportation.

The current version used for experiment in our paper is a version only for internal test of the agent-based technology. By a primary test, the characteristics are identified as follows:

- J2SE Development Kit 5.0 Update 11 is needed for running the system.
- It is required that the computer has not less than 1 GB RAM, preferably 3 GHz.
- The input and output files are only .xml format, it is not easy to read and compile, the other information can only be read through computer interface.
- Only one type of truck is supported.
- Types of product are not differentiated.
- The match of driver, truck and trailer is not supported.
- Loading sequence is not supported.
- The sites are located by latitude and longitude, the distance is calculated by the latitude and longitude with road parameters, not the real routes.
- Only one distribution centre is supported, that means all the vehicles start from one location and end at the same location.

The experiment was conducted with Magenta's i-Scheduler for road transportation and based on Manor Bakeries' transportation planning. Although this is a company-based study, the findings will provide all the companies in the freight transport and logistics domain with relevant information about the development and application of agent-based technology.

IV. ANALYSIS OF RESULTS AND EVALUATION

The aims to measure the performance of the agent-based software tool, compare the experiment results with current performance, and evaluate the results of agent-based approach for Manor Bakers' transport planning. To achieve this, an evaluation matrix is first designed for evaluating the experimental processes and results. The results of the experiment are analyzed and compared with Manor Bakeries' manual scheduling. The differences between the two scenarios: standard period and peak period are analyzed.

A. *Evaluation Matrix*

1) *Choice of KPIs*

To analyze and the experiment, a structured evaluation matrix is designed. the matrix includes a set of KPIs, fleet mileage; fleet capacity utilization; empty running ratio; the number of truck used and the transportation cost (Mckinnon, Ge and Leuchars, 2002).

- Fleet Mileage is the sum of the total Miles traveled within a specified time period.
- Fleet capacity utilization is expressed as the ratio of the actual number of pallets carried to the maximum number possible.
- Empty running ratio is the ratio of empty travel distance to the total travel distance for all journeys within a specified time period.
- The number of truck used is simply a count of the total numbers of trucks used in the transport operation within a specified time period.
- Transport cost is a synthesized KPI. It is calculated in a simplified model. Transport Cost = Running

Cost + Fixed Cost, (Running Cost: 80 Pence per Mile, Fixed Cost: £ 100 per Day).

B. *Analysis of Results*

1) *Scenario one-Standard period*

The data used in scenario one is extracted from the actual planning data of Thursday, 14 June 2007. This day is a typical day in a standard period. In this scenario, there are 37 orders in total, 1066 pallets of products need to be delivered or collected. All the deliveries and collections are within England with most of the orders concentrated on London, the North West and the Midlands.

The planning results obtained using i-Scheduler show that 25 journeys are planned, utilising 11 trucks. The KPIs: capacity utilization, empty running and transport cost cannot be given directly by the software tool, which were calculated based on the detailed information of each journey.

In Manor Bakeries' actual plan, the KPIs used in this research are not included in the cost-to-serve model. Then all the KPIs were calculated manually using the same parameters as that used in i-Scheduler experiments.

TABLE I. SCENARIO ONE: THE KPIS AND COMPARISON

KPIs	Fleet Mileage (Miles)	Fleet Capacity Utilization (%)	Empty Running Ratio (%)	Number of Truck Used/Journeys	Transport Cost (£)
Existing Performance	4050	70.55%	33.1%	17/25	4940
Planning with i-Scheduler	4045	82%	33.42%	11/25	4336
Changes	- 0.1%	+11.45%	+0.32%	-6	-12%

Table 1 provides a comparison of the results obtained using i-Scheduler against the manual planning approach. It can be seen that the fleet miles are almost the same, the difference is only 0.1%. Although the fleet capacity utilization increased by 11% using i-Scheduler planning, the empty running ratio increased by 0.32%, this cannot be regarded as an improvement. The trucks used reduced from 17 to 11, which is a significant improvement. However, the i-Scheduler planning does not consider some practical factors such as driver unavailability, the cost to serve, and truck maintenance. In practice, the number of trucks may be more than 11. The transport cost reduced by 12% mainly due to the reduction in the number of trucks.

The KPIs show that for a standard period scenario, the planning results of i-Scheduler do not provide significant improvements over Manor Bakeries' manual planning approach. The reasons for this are discussed. Firstly, this standard scenario is simplistic, and it is not very difficult to create an optimum schedule manually. The template of Manor Bakeries transport planning is first scheduled by the tool LogiX DPS, and adjusted with operational experience. In this kind of simple scenario, there is little margin for improvement. Secondly, in theory, the results of agent-based technology are not the most optimized compared with the deterministic algorithm in dealing with the non-complex problems according to the conclusion of literature review.

In conclusion, in this simple scenario, the i-Scheduler does not present any advantage over Manor Bakeries' manual planning approach. This result suggests that an agent-based approach does not offer any advantage in solving this kind of non-complex problem.

2) *Scenario two-Peak period*

The data used in scenario two is extracted from the practical planning data of Friday, 29 November 2006. This day is within the Christmas peak period. In this scenario, there are 65 orders totally, and 1906 pallets of product need to be delivered or collected. The orders and volume are almost double that in scenario one. More depots and delivery locations make the transportation network and the task of planning more complex.

The planning results obtained using i-Scheduler show that 40 journeys are planned and 24 trucks utilised. All the detailed figures of the experimental results and actual plan are illustrated in table 8.2, the parameters used for calculating the KPIs are as same as scenario one.

TABLE II. SCENARIO TWO: THE KPIS AND COMPARISON

KPIs	Fleet Mileage (Miles)	Fleet Capacity Utilization (%)	Empty Running Ratio (%)	Number of Truck Used/Journeys	Transport Cost (£)
Existing Performance	8494	72.78%	39.3%	35 /47	10295
Planning with i-Scheduler	7174	82.56%	28.5%	21 /40	7839
Changes	-15.5%	+9.78%	-10.8%	-14	-24%

Comparing the i-Scheduler results with the practical planning, it can be seen that all the KPIs have significant improvement. The fleet miles reduced by 15.5%. The fleet capacity utilization increased by 9.78%, empty running ratio decreased by 10.8%. There are 14 trucks reduced in the i-Scheduler planning, and the transport cost reduced by 24%.

In conclusion, in the peak scenario, all the KPIs are improved by using i-Scheduler. This shows that in a complex environment, the agent-based approach is better at planning than Manor Bakeries' current manual planning approach. Comparing the improvements of these two scenarios, it can be concluded that the agent-based approach has more advantages in solving the more complex problem in scenario two.

3) *Benchmark*

The experimental results and the practical operational performance are compared with the average performance of transportation in the UK food industry. A Key Performance Indicator survey conducted by Heriot-Watt University is used for benchmarking [6]. Two KPIs are selected for comparison: fleet capacity utilization and empty running ratio. These two KPIs are the most important factors that influence transport efficiency. In the survey results, it is shown that average fleet utilization is 69%, and the empty running ratio is 21.5%. The fleet capacity utilization of Manor Bakeries' practice and the

results of i-Scheduler are better than the average level in UK' food industry. However, Both Manor Bakeries' practice and the results of i-Scheduler in terms of the empty running ratio is not as good as the average level. For the i-Scheduler result of scenario two, the empty running ratio is 28.5%, it is close to the average level comparatively.

TABLE III. BENCHMARK ANALYSIS

Scenario		Fleet Capacity Utilization (%)	Empty Running Ratio (%)
Scenario One	Existing Performance	70.55%	33.1%
	Planning with i-Scheduler	82%	33.42%
Scenario Two	Existing Performance	72.78%	39.3%
	Planning with i-Scheduler	82.56%	28.5%
Benchmark		69%	21.5%

The benchmark results show that it should have margin for improvement in the empty running of Manor Bakeries. Of course, this is decided by Manor Bakeries' physical network and order characteristics. However, with the planning of i-Scheduler, it can be improved by almost 10%.

4) Special events test

Three special events are tested in the experiments.

Event One: last minute order. A last minute order arrives when all other deliveries have been planned.

Event Two: Route unavailability. Due to the traffic, the planned routes are unavailable.

Event Three: Order cancellation. A planned order is cancelled.

Because the i-Scheduler has the characteristic of continuous scheduling, Event one is treated as a normal order. It can be input directly and the software adds this order to the uncommitted orders. Occurrence of Event two, if the truck has been dispatched, it is too late for the i-Scheduler to find the optimized route from the truck's location. If the truck has not departed, the journey can be collapsed and rescheduled. If an order is cancelled (Event three), the solution is also to collapse the journey and reschedule.

5) Limitations

Due to this version is only for internal testing, not the final version for customers, there are some limitations exists.

- Only one type of truck is supported;
- Types of product are not differentiated;
- Every load with every truck with every location are considered to be compatible;
- Trailer entity and trailer swap is not supported;
- Driver entity and schedule is not supported;
- Loading sequence is not supported;
- Load weight is not considered, only volume;
- Length of operation does not depend on order volume.

If the i-Scheduler is to be deployed, it needs to be further developed to overcome the limitations identified.

V. CONCLUSIONS

In this paper, we study on agent-based approaches to transport logistics. The experiment results are analyzed and evaluated. Based on the findings presented, following conclusions can be drawn: The i-Scheduler does not show many advantages in solving non-complex transport scheduling problems. For more complex scenarios, i-Scheduler can improve performance over and above that achieved using a manual planning approach. The agent-based scheduler can provide continuous planning; it is convenient for dealing with the special events such as last minute orders, truck breakdown, etc. As an event occurs the scheduler rapidly re-schedules only the affected part of the schedule thus causing the minimum disruption to already allocated resources. From the experiment results, it can be seen that agent-based technology is suitable for solving the distributed, complex and volatile scheduling problems in the road transport domain.

REFERENCES

[1] Davidsson, P. et al., "An analysis of agent-based approaches to transport logistics." Transportation Research Part C: Emerging Technologies, 13(4), pp. 255-271. 2005.

[2] Perugini, D. et al.., "Agent-based global transportation scheduling in military logistics". In Autonomous Agents and Multiagent Systems, AAMAS 2004, New York, USA, July 19-23 2004, pp. 1278-1279.

[3] Sawamoto, J. ,"Truck delivery scheduling system with a mobile communication feature". International Journal of Information Technology, 8(1), pp. 26-39. 2002.

[4] Mes, M., Heijden, M., and Schuur, P., "Opportunity costs calculation in agent-based vehicle routing and scheduling". Beta Working Paper Series, WP-168. 2006.

[5] Pechoucek, M. and Marik, V.,. "Review of Industrial Deployment of Multi-agent Systems." http://agents.felk.cvut.cz/publications/marik.html (accessed 10th May 2007)., 2007

[6] Mckinnon, A., Ge, Y. and Leuchars, D. , "Analysis of transport efficiency in the UK food supply chain: Full report of 2002 key performance Indicator survey". Heriot-Watt University, Edinburgh, UK., 2002.