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Assessment of Telecommunication-Supported Dynamic Vehicle Routing Strategies

Lorenz M. Hilty¹, André J. Rogger² and Frank A. Hartmann³

Abstract

We describe the application of a simulation model in the domain of dynamic vehicle routing. This model allows for the assessment of optimization potentials in terms of distance, cost and energy savings. Telecommunication between trucks and their central dispatchers has made it possible to react to short-term orders and traffic disturbances. Therefore it is advantageous to go from a static to a dynamic strategy of vehicle route planning. Then a company must ask how to deal with orders coming in on short notice and what consequences different strategies to handle these orders have on the length of distances driven and the utilization of trucks. Our simulation model is able to answer this question using a sample of the data from one trucking company for its specific situation. All constraints relevant in practice are used in the form of corresponding parameters such as different capacity limits of vehicles, the number of vehicles, drivers' working times, etc. An additional parameter makes it possible to vary hypothetically (0-100%) the percentage of orders considered "dynamic", i.e. the ones that have to be integrated into truck routes that are already proceeding. In this way the relative value of different strategies to solve an instance of the Dynamic Vehicle Routing Problem (DVRP) can be simulated given different dynamic shares. Important output variables include the sum of distances driven, the associated costs for the company and the environmental impact. Our model was used to study a Swiss trucking company as an example. It became apparent that the dynamic share influences the total distance driven very differently depending on the strategy chosen.

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1. Introduction

Modern telecommunications makes it possible to do dispatching of vehicles much more dynamically. However that causes increased complexity, as decisions have to be made within very short times. Traditional optimization strategies come up against their limits here. They often are built on the assumption that the problem to be optimized is static, and that an optimal solution has to be found for that. However with the dynamism that goal disappears gradually. The challenge then consists of *inserting new short term jobs into the transport process optimally*. The optimal initial solution is becoming more and more irrelevant then because of the indeterminism of these events. It is more important to have an appropriate *strategy or policy*.

New orders have to be integrated into tours that have already started. Whenever a vehicle is delayed because of a traffic jam or breakdown, the trip to the customer waiting for a delivery may have to be re-planned so that deliveries can be made as promised. Then the problem becomes a classic pickup and delivery problem, in which any location can serve as a pickup point. In order to cope with this situation, one has to know the current position of the trucks and their remaining jobs.

A new order can be integrated into the tour which has the lowest additional costs (“cheapest insertion policy”). However since additional short term orders can show up, this strategy is often too myopic and hinders unnecessarily the carrying out of the tours. This disadvantage can be overcome by using a “batching policy”: those orders that have not yet been scheduled are held back until the most urgent one cannot be delayed any longer. Then all collected orders are spread over the existing tours as well as possible. Since the pick-up location is often the depot, of course, new tours result.

Based on the real-time information that one gets from the truck drivers, the latest possible time can be waited for with dispatching. Then new plans can be made and finally communicated to the drivers over their on-board computers. Thus it becomes apparent that delaying short term deliveries as long as possible and integrating them in batches into the current solution might be better than to attempt to integrate every order into existing routes immediately. However, there is no general answer to the question which strategy or policy for coping with dynamic orders is the best one, because it depends on the distribution of orders in time and space as well as of a set of situation-specific constraints.

Given this problem, we developed a simulation model which can be used to assess the impacts of different strategies on the length of distances driven and the utilization of trucks. The model, mainly developed by the second author, uses a sample of data gathered in the specific trucking company under study. All constraints relevant in practice are used in the form of corresponding parameters such as different capacity limits of vehicles, the number of vehicles, drivers’ working times, etc. Another parameter makes it possible to vary hypothetically (0-100%) the percentage of orders considered “dynamic”, i.e. the ones that have to be integrated into truck

routes that are already proceeding(“dynamic share”). In this way the relative impact of different strategies to solve an instance of the Dynamic Vehicle Routing Problem (DVRP) can be simulated given different dynamic shares.

The model is implemented in Java and produces XML output files. A more detailed description of the model will be published in a scientific journal.⁴

2. Sample application of the model

Let us compare two simple strategies for optimal integration of dynamic orders as regards their effects on the distances driven taking the Frigotransport AG (Switzerland) trucking company as an example. One of the purposes of the comparison is the assumption that the dynamic share will rise in the future.

- **Strategy 1:** With the first optimization strategy short-notice orders are integrated into running routes optimally as regards time and costs, as they come in. Orders that have already been planned are not changed.
- **Strategy 2:** The second optimization strategy combines into a new route each short-notice order with those that have not yet been taken care of, although they have already been scheduled with the aid of the "Cheapest Insertion" algorithm. Thus, routes that had been planned and optimized for the static case are destroyed in favour of a new route planning.

At first we compared both strategies on the basis of empirical order data from Frigotransport AG (status quo). In order to test the influence of dynamic orders, the percentage of total orders comprised by the dynamic orders was hypothetically increased in steps of 10% per simulation run.

Since we anticipated that the share of *pickup-and-delivery (P&D) orders* would change in reality, we also tested the influence of this parameter for both strategies.

As was to be expected, increasing the dynamic share causes an increase in the total distance driven (cf. Fig. 1). The simulation covered one average working day of the company. Note that the “dynamic share” parameter only influences the time when a part of the orders *becomes known* to the company, i. e. the time when a part of the information needed for planning is available. This parameter does not affect the amount of goods transported nor the place where they have to be picked up or delivered nor the time constraints for pickup or delivery. If the total distance driven increases under the influence of this parameter, as can be seen in Figure 1, this is due to a deviation from the optimal solution.

⁴ Please contact the authors if you are interested in further information.

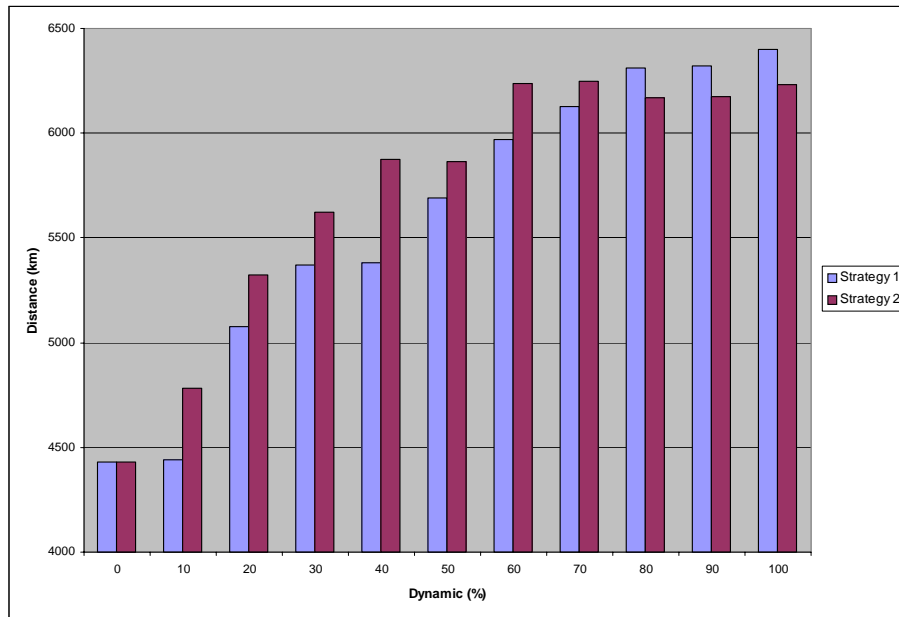


Figure 1:

Comparison of total distance driven for two optimization strategies and different dynamic shares (reference scenario: 7700 km)

In order to compare the solutions found to the worst case, a reference scenario was simulated in which there is no route planning at all, i.e. each order is treated independently of the other orders (one route per order). In the case we use to show the application of the model, the reference scenario produces a total distance driven of 7700 km.

As Figure 1 shows, the increase is approximately linear up to a certain point (80-85% of the worst-case distance). With Strategy 1, though, which tries to maintain the result of the original planning as far as possible (i.e. the planning on the basis of the part of the orders known in advance) the distance stays constant starting with approximately 80% dynamic share. That means that starting with approximately 80% dynamic share the problem is purely dynamic in nature. The information from 20% static orders known in advance can then hardly be used at all for a reasonable route planning.

The two optimization strategies give very similar results given the specific situation of the company investigated. Up to a share of approximately 70%, Strategy 1 shows slightly better results, whereas over 70% dynamic share the relation is reversed. This can be explained by the fact that information from static planning can

no longer be used with such a strongly increased dynamic share – Strategy 1 builds upon static planning, whereas Strategy 2 plans completely anew.

Changing the P&D share to P=50%, and D=50%, i.e. no combined P&D orders exist any more (Fig. 2), yields similar results. Strategy 2 looks worse, even given a very high dynamic share, a phenomenon caused by the lack of complicated combined P&D orders. At the beginning, at 10-30% dynamic share, the difference is large.

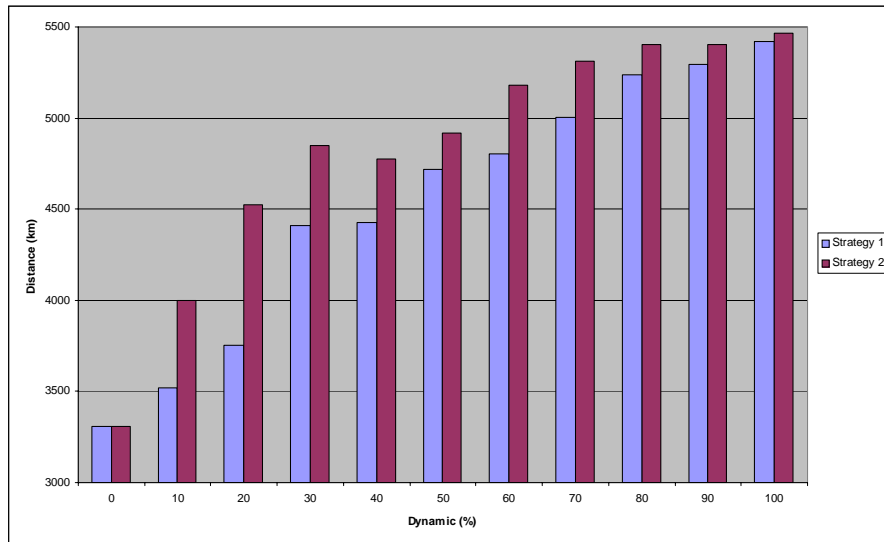


Figure 2:

Comparison of total distance driven for two optimization strategies and different dynamic shares and different dynamic shares, given 0 % Pickup-and-Delivery orders (reference scenario: 6400 km)

The earlier the dynamic orders arrive, the better they can be integrated into existing routes. In the scenario upon which Fig. 1 and Fig. 2 are based, the dynamic orders arrive on a mean of 240 minutes, with a standard deviation of 60 minutes. The scenario in Fig. 3, on the other hand, assumes that orders arrive after a mean of 60 minutes, with a standard deviation of 15 minutes. One sees that the increase in distance then drops as expected. In addition one can see that Strategy 2 shows up much better given early appearance of the orders. This difference is accentuated when given larger dynamic shares. Whereas with Strategy 1 the initial routes are only expanded, but not planned anew, with Strategy 2 almost all routes can be planned anew after the dynamic orders arrive. Given a low dynamic share, the advantage of a planning

anew does not matter, or matters very little as the differences to the set plan hardly matter. This can be seen clearly in Fig. 3, up to a dynamic share of approximately 40%.

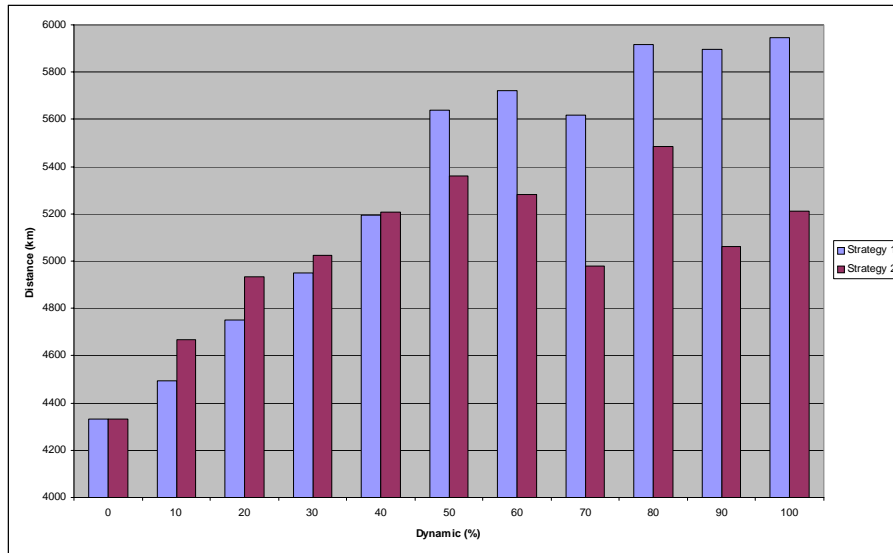


Figure 3:

Comparison of total distance driven for two optimization strategies and different dynamic shares given early appearance of dynamic orders (reference scenario: 7600 km)

Sensitivity analyses with regard to other important parameters (such as volume and weight of orders) showed that the results described above are not influenced substantially.

3. Conclusion

We have shown using a practical example how our model can be used to help a company adapt to the increasing dynamic of demand for trucking services. One prerequisite is that dynamic vehicle routing can rely on having modern telecommunication facilities available. Then a realistic simulation of the entire process from order arrival to route planning to executing the routes can be done on the basis of customer addresses and a random sample of the company's order data (for instance, over two weeks as in our case). The model makes possible hypothetical variation of

order structure and fleet properties. It is therefore valuable to company management for decision support, whenever management is confronted by rising requirements concerning flexibility and reaction time and must decide which measures are most effective in the company's specific situation, in order to maintain efficient route planning, or to further increase its efficiency.

Whenever the approximate time distribution of "dynamic" orders is known, managers can decide which optimization strategy should be used on the basis of accurate simulation experiments, and how much expense is justified, in order to get the maximum benefit for the company, as well as to minimize energy consumption.

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Bibliography

- Hartmann, F. A.; Rogger, A. J.; Hilty, L. M. (submitted): A Simulation Model for the Assessment of Telecommunications-Supported Dynamic Vehicle Routing Strategies. *Computers & Industrial Engineering*.
- Hilty, L. M., Meyer, R., Ruddy, T. F. (2001). A General Modelling and Simulation System for Sustainability Impact Assessment in the Field of Traffic and Logistics. In: Rautenstrauch, C. (ed.), *Environmental Information Systems in Industry and Public Administration*, Hershey (PA) Idea Group Publishing, 167-185.
- Larsen, A. (2000). *The Dynamic Vehicle Routing Problem*, Ph.D. Thesis. IMM-PHD-73, Informatics and Mathematical Modelling, University of Denmark, Denmark.
- Powell, W. B., Towns, M. T., Marar, A. (1991). On the value of globally optimal solutions for dynamic routing and scheduling problems. *Transportations Science*, 34 (1), 50-66.
- Regan, A. C., Mahmassani, H. S., Jaillet, P. (1999). Dynamic fleet management for trucking operations. In: World Markets Research Centre (eds.): *Global Truck and Commercial Vehicle Technology*, 31-35.
- Rogger, A. J., Hartmann, F.A., Zah, R., Ruddy, T. F., Hilty, L. M. (2001). Optimization Strategies for Transportation Systems Using Mobile Telecommunications, In: Hilty, L.M., Gilgen, P.W. (Eds.): *Sustainability in the Information Society*. 15th International Symposium Informatics for Environmental Protection, Zurich 2001. Metropolis Verlag, 623-630.
- Schrijver, P. R. (1993). *Supporting fleet management by mobile communications*, Ph.D. Thesis, Delft University, The Netherlands.