Decision Making for Time-Constrained Commodity Transportation

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Abstract

“Xenios” is a specific DSS that was developed to assist the daily VRS activities of Greek transport firms during special events. This system incorporated essential functions of GIS, database systems and model management techniques to support overall routing, scheduling and decision-making processes for Vehicle Routing and Scheduling (VRS) problems encountered during the Athens 2004 Olympic Games (ATHENS 2004).
During the Athens Olympic Games 2004 in Athens, the Vehicle Routing and Scheduling problem was very intense. Actually, the commodities transportation had to be done within strictly defined time-periods and under many security and traffic restrictions [2, 8].

Our work aimed at the successful setting up of DSS “Xenios” so that it could cover a wide range of variations of the VRS problem, especially problems with hard time-windows in the route generation [15, 17].

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1 Standing VRS problems and decision-making

Trying to develop a specific Decision Support System (DSS) for VRS activities of transport firms, during ATHENS 2004, came up with the need to survey the various problem dimensions [14] and create a theoretical framework for the specific context. This would assist us with the successful setting up of the DSS “Xenios” which covered a wide range of variations of the VRS problem encountered by transport firms during the Olympic Games 2004. The main difference of this system from a previous DSS named “Dromones” [14] was the aspect of hard time-windows in route generation. Therefore, the process of VRS decision-making was considered as a quite rigorous one [17]. The system combined GIS features, database management system and several model management techniques to support routing, scheduling and decision-making processes needed by general transport firms [15].

Dantzing & Ramser [6] were the first to present the mathematical definition of the vehicle routing problem. In simple words, the problem focuses on the delivery of certain quantities of commodities to a number of customers who are scattered throughout a geographical area. A certain number of vehicles are available for these deliveries and each vehicle has a given capacity. Our aim is to determine a set of routes that each one would start and finish in the depot so that the overall covered route can be minimized always under the conditions that all orders are being served and the issue of time-windows is taken into account. Datzing & Ramser define the following specifications explicitly [6]:

- A set of n points \( P_i \) \((i = 1, \ldots, n)\), in which all orders are being delivered from a point \( P_0 \) (the depot).
- A quantity of orders \( q \) that has to be delivered in \( P_i \) \((i = 1, \ldots, n)\).
- The capacity of the truck is \( C \) \((C > q_i \text{ for } i = 1, \ldots, n)\).
- A matrix of routes \( D = [d_{ij}] \) that defines the route between each pair \((i, j = 0, \ldots, n)\).
The objective is to find a set of routes that each would start and end at point $P_0$, in order to minimize the overall covered route from the trucks under the condition that all orders are delivered and the capacity of all trucks is respected.

There are a number of variations as far as the denomination of the present problem is concerned. Consequently, the present problem will be called as a classical vehicle routing problem (CVRP).

The grouping of the problem dimensions aimed to the formation of dimension groups with common characteristics. Several came from the relevant bibliography [1], [3], [4], [5], [7] while others revealed from the field research conducted in various firms [13], [15]. Based on this groundwork, the formulation of the conceptual schema for the necessary database and the DSS rules definition were accomplished without any severe problems (see fig1).

### Outcome measures

The outcome is characterized by the synthesis of the solution factors and the consumed resources for its achievement. The consumed time for the outcome achievement is the main point of the resource consumption.

The studied measures constitute an initial set of measures based on the general expectations as regards the VRS problem type and the applied DSS method. The absolute and relative significance of each measure depends on each decision-maker [13]. Moreover, each decision-maker could set additional measures that would be relevant, according to ones personal opinion, with the
framework of the specific VRS problem (here is the case of commodities transfer within strictly defined time-periods and under many security and traffic restrictions).

The above table includes a number of preliminary measures regarding economical aspects; levels of customer service and driver working conditions related to the solution factors [13], [18] applied for VRS problems during special events, like ATHENS 2004.

The overall evaluation is generally a synthesis of specific measures and estimations of their relevance with the problem according to the perception of each decision-maker [14], [16]. Using his/her intuition and based on his/her subjective valuations, the decision-maker could select one of the following route patterns:

- Pick up
- Delivery
- Delivery and pick up when the vehicle returns (backhaul)
- Pick up and delivery when the vehicle returns (reverse-backhaul)
- Combination of pick up and delivery

The decision-maker options aimed to satisfy the goals set by each transport firm as regards as the route generation, namely,

- To serve as many as possible customers within the firm working hours (06.00–22.00)
- To serve the regular customers with priority
- To retain the service consistency regarding the new customer orders (hard time-windows)
- To respect the standing traffic and security restrictions
- To keep route costs down, especially the elastic expenses like fuel consumption etc.

In this aspect, the use of “Xenios” allowed the decision-maker and the firm respectively

1) To create pick-up and delivery combinations based on the firm priorities
2) To select the best route option, based on the available data, for each case
3) To intervene for the adjustment of the resulted solutions (routes) in dynamic situations like happenings, security measures, outdoor events (like marathon race) etc.
3 Decision-making facilitated by the DSS “Xenios”

The main goal of the specific DSS “Xenios” was to facilitate the decision-maker in the processing of the next day orders and generating feasible routes depending on the chosen service pattern [15]. The last was specified on the basis of the firm’s current goals.

The decision-maker knew, from the previous day, the number of customers that demanded service for the next day, their order quantities, their time limitations (time-windows) as well the service kind, namely, delivery or pick up. In our case, the customers could demand either delivery or pick up. They couldn’t ask both on the same time. The decision-maker was also aware of the number of vehicles that he could use in a route, their transport capacity as well as the standing traffic and security measures [2]. In our case, all vehicles were of the same type; therefore they had the same capacity. There was a specific working hour schedule for the vehicle crews. In this schedule, there was an obligatory pause of 30 minutes at noon (considered as a mandatory waiting time).

During special events, the decision-maker sets the service of as many as possible customers as a main objective [15]. He seeks the maximum performance of the used firm resources i.e. vehicles, drivers etc. His intention is to get the maximal utilization of the vehicle capacity and to expend into the
maximum the working hour schedule of the vehicles and the drivers. The
decision-maker’s intentions are altered when the total quantity of the existed
orders is less than the total transport capacity of the available ve-
hicles. Then, he sets as a main goal the reduction of the varied route cost through the min-
imization of the total route time. In that case, an additional goal comes up.
The exploitation of firm resources that remain free after the route termination.
This goal doesn’t concern only a specific route but the routing and scheduling
process as a whole. During ATHENS 2004, the decision-maker could satisfy
the above demand in two ways
a. To generate a new route that will take into account the rest time
period for the working hours completion
b. To reschedule the derived route in order to service all delivery and
pick up orders that exist

The final routes could be evaluated by using alternative utility functions
[13], which indicatively included measures like:
- Total route time
- Total cost of vehicle utilization
- Violation number of the customer time-windows (hard)
- Declination percentage between actual and desirable working hours
  (or vehicle traveling) schedule

The significance (influence) rate of each measure could be determined with
regard to each decision-maker’s perception about the above measures or other
similar [16], [11]. For the DSS “Xenios” were selected several measures (trans-
port firm goals) of the above table, which were classified in two sets:

A. Total order quantity ≤ vehicle capacity
   a1 Minimization of route time
   a2 Minimization of the vehicle utilization cost
   a3 Minimization of the customer time-windows violations
   a4 Keeping of working hours (or vehicle traveling) schedule

B. Total order quantity > vehicle capacity
   b1 Maximization of serviced customers’ number (with priority)
   b2 Maximization of the vehicle plentitude (serviced quantities/capacity)
   b3 Minimization of the vehicle utilization cost
   b4 Keeping of working hours (or vehicle traveling) schedule

The selection and classification of the above goal sets was based on the
manual route generation process of the transport firms. These goals represent
the way that the involved firms and respectively their people (decision-makers)
perceived the whole VRS process during a special event like ATHENS 2004.
It might be pointed out that in our case, in the vehicle utilization cost was
included the fuel cost together with the vehicles’ damping cost (purchase, rental
or leasing), the maintenance cost and the spare parts cost.
4 Conclusions

The first step in the development of any specific DSS is the identification of the applying problem dimensions [3, 7, 10]. In order to make the development procedure easier, we tried to classify the most significant VRS problem dimensions that had common characteristics in groups. The Vehicle Routing and Scheduling (VRS) process of Greek transport firms, during the Olympic Games 2004, could be served by means of a specific Decision Support System (DSS), named “Xenios”. Actually, the necessary decision-making is more complicated than usual since in such events many security and traffic restrictions exist [2, 8]. This means that the VRS activities have to be accomplished within strictly defined time-periods (hard time-windows) and under time-limitations [2].

The development of specific Decision Support Systems can be done by the use of databases and Geographical Information Systems [14]. The present identification and grouping of the various VRS problem dimensions (factors) can actually be helpful to anyone trying to develop a specific DSS for transport activities during special events. In this paper, we present the most significant dimensions that have been derived from the analysis of various well-known VRS problems [4, 5, 9, 12, 17]. Any dimension of strategic nature has purposively been excluded from our survey and only dimensions of operational and tactical problems have been included [13, 15]. This dimension type should be a future research objective in order to develop an integrated DSS for VRS activities.

References


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