Depannage and other Maintenance Strategies for Transportation Fleets

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Abstract: This paper addresses the problem of designing a depannage service network for freight transportation fleets in order to fill up an evident gap in Operations Management literature. As a matter of fact, breakdowns have a significant impact on service level and an efficient and effective assistance service is needed in order to guarantee competitive advantage. Aiming at laying the foundations for further research on modelling and solving the considered problem, a literature review is performed for identifying analogies with other problems, already approached in the past, and stating the problem. Finally, parameters, decision variables and objective function that should be considered for modelling and solving the problem are proposed, trying to stimulate the discussion on a new research theme and, more specifically, on the integration of decisions at strategic, tactical and operational level into a systemic model.

Keywords: Fleet Management and Maintenance, Depannage, Transportation Systems, Spare Parts Inventory Management, Network Design

1. Introduction

Throughout the supply chain, one factor that influences manufacturer's competitiveness is on-time delivery of orders. Nowadays it is not enough to merely know you are on-time, but it is also important to know just how much you are on-time (i.e. knowing raw material delivery in order to organize on-time production). Indeed, supplier performance has never been more crucial to manufacturing success than it is today. Factors such as sourcing from suppliers in different countries, extended supply chains, unstable supply markets as well as a general supply risk and outside processing all conspire to impede on-time delivery. In particular, most of companies externalized a fundamental activity as products distribution to the so called "3PL" (Third-Part Logistics Service Providers), this reduces the control on the delivery time. Moreover, service level in this business is strongly affected by environment variables: a minimal variation of travel lead times for a single vehicle – due to accidents, traffic conditions, weather or technical malfunctioning – may propagate to the entire fleet influencing the whole deliveries planning. In this contest, logistics and maintenance are the levers to control the delivery time: logistics help in deciding the faster way to arrive at destination while maintenance aims to decrease the uncertainties due to failures. Thus it is particularly interesting to analyze maintenance strategies for transportation service providers, where the strict integration between logistics and maintenance shows a significant impact on the company budget.

In Europe, the amount of goods transported by road is increasing on average 3.9% every year representing the 47.02% of the total goods movements in 2009 because of the particular configuration of the territory and the different infrastructure from country to country. Analysing in Italy in 2007 truck traffic flow was estimating to be 11,419 million of vehicles per km (EUROSTAT, 2009) and considering that the percentage of mechanical failure (mostly brake, tyres and steering and suspension failures) is around 5.3% (International Road Transport Union, 2009) the impact can be estimated around 605 million of vehicle per km per year. Italian National Carrier Association (Albo degli Autotasportatori) estimates that in Italy in January 2008 the cost of road haulage is 1.55 € per km and 76 € per hour, thus in one year applying the right maintenance strategies can be saved in the overall transport system 294.68 million of € per vehicle. Taking into account exclusively the operational cost spent for the truck stops it is possible to calculate that for 3-5 hours of stop an Italian company is spending from 228 to 380 per vehicle. As demonstrated with previous data for 3PL a careful implementation of maintenance strategies has to deem the unforeseen events such as truck mechanical failure on road. Furthermore, seeing the problem form sustainability point of view, truck failures have a strong impact on traffic and safety on road. European Community studies on transport system stressed that trucks causes in urban areas around the 60% of traffic and in highway around the 40%, while they affect road accidents in the measure of 5% (International Road Transport Union, 2009).

Having strict constrains on time and costs, 3PL have definitely to take into consideration this events, nevertheless fleet routing in large geographic areas implies the ability to perform maintenance operations at any moment as soon as possible, in order to quickly restore the productivity of the vehicles and this interventions determine anyway an unexpected cost difficult to control. At the present interventions are mostly performed through a network of assistance provider but they may be managed also directly by the company. This process requires an effective control and resources coordination to minimize downtime risks and service delays. In order to control and find an optimal solution it is needed a deep analysis of the problem. It involves decisions about: fixed and mobile workshop location, generally said network design; spare parts management (monitoring and replacing) either on mobile vehicle than in workshops; calls allocation to different mobile workshops and the fastest routing to reach truck position. In the present paper are laid the basis for a problem analytical description and integration, trying to model it finding decision variables, objectives and parameters.

2. Problem Description and Literature Review

Given a set of events (i.e. truck breakdowns), the problem is to design an assistance service network for freight transportation vehicles, that has to guarantee a defined service level and, at the same time, minimize overall cost function. So defined, the problem implies the statement of three main sub-problems:

- *Workshop Location Problem* (WLP), that includes the selection of workshops in a set of eligible ones, the allocation of breakdowns to workshops, the identification of the number and the location of mobile workshops in the network;
- *Mobile Workshop Routing Problem* (MWRP), i.e. the assignment of a subset of breakdowns to each mobile workshop and the determination of routes to follow;
- *Spare Parts Inventory Control Problem* (SPICP), i.e. the determination of inventory level and replenishment policy for each workshop.

As already said, there are no relevant studies about the analyzed problem, but a broad-spectrum literature review showed several common points with other "most popular" problems. In particular, the design of an assistance service network is easily (but not totally) having reference to distribution network design. Recently, Javid and Azad (2010) observed that the latter problem is usually divided into three sub-problems: Location-Allocation Problem, Vehicle Routing Problem and Inventory Control Problem. By this way, they presented an integrated model to simultaneously approach these problems in a stochastic supply chain system, in order to consider their high interdependency. Works with similar aims were reviewed by Dror et al. (1985), Campbell et al. (1998), Baita et al. (1998), Sarmiento and Nagi (1999), Moin and Salhi (2007) and Andersson et al. (2010) for the Inventory Routing Problem (IRP); Min et al. (1998), Nagy and Salhi (2007) and Hassanzadeh et al. (2009) for the Location-Routing Problem (LRP); Kaviani, M. (2009) for the Location-Inventory Problem (LIP). Analogously to these contributions, the proposed model aims at integrating decisions that take place in different decision levels (strategic, tactical and operational) and that usually are considered separately for modelling purposes, in spite of evident interactions between them. However, there are several points to be discussed for understanding what have in common the analyzed problem and distribution network design and what instead are differences. For this purpose, the three sub-problems identified by Javid and Azad (2010) are now discussed one-by-one, in order to compare:

- Location-Allocation Problem to Workshop Location Problem;
- Vehicle Routing Problem to Mobile Workshop Routing Problem;
- Inventory Control Problem to Spare Parts Inventory Control Problem.

2.1 Location-Allocation Problem vs. Workshop Location Problem

Location-Allocation Problem (LAP) was introduced by Cooper (1963) and most relevant review papers were by ReVelle et al. (1970), Francis et al. (1983), Aikens (1985), Tansel et al. (1983), Owen and Daskin (1998) and Azarmand and Neishabouri (2009). Cooper stated the problem as follows: given the location of each destination, the requirements at each destination and a set of shipping costs for the region of interest, to determine the number of sources, the location of each source and the capacity of each source. The considered workshop location problem may be stated in an analogous way: given the location and requirements of each breakdown and a set of costs to determine: the number of workshops, their location and capacity. Despite of their similar definition, the problems differ in several points. First of all, in LAP destinations correspond to customers with a certain location and a certain demand which can be deterministic or stochastic; each customer is generally served several times during the considered planning time horizon and his allocation is fixed to a facility at the beginning of the planning time horizon. Instead, the WLP deals with truck break downs that are always in different locations and must be served within a certain time period. LAP requires satisfying a demand of a certain product; here a certain service time must be guaranteed: a time window is associated to each destination, starting when the break down occurs and ending when the guaranteed service time expires. In this sense, the considered problem is analogous to the design of an emergency medical service (EMS) network that concerns service sites location, vehicles location and, above all, the level of reliability to guarantee. Relevant works about EMS were by Davis (1981), Daskin and Stern

(1981), Daskin, M.S. (1982), Eaton et al. (1985), Beraldi et al. (2004) and Beraldi and Bruni (2009). Focusing on Ambulance Location and Relocation sub-problem, Brotcorne et al. (2003) provided a comprehensive literature review, recently updated by Schmid and Doerner (2010). The main differences of EMS compared to WLP design are that all demand locations must be reached within a certain number of time units and that a certain percentage of the population must be reached within an another number of time units, typically minor than the previous one. These two conditions are also fundamental for locating workshop location, given service level requirements.

2.2 Vehicle Routing Problem vs. Mobile Workshop Routing Problem

Vehicle Routing Problem was addressed for the first time by Dantzig and Ramser (1959) as an extension of the most famous Travelling-Salesman Problem (TSP). Given a fleet of vehicles located in one or more depots, a set of customers, demand and location of these customers and a road network, VRP deals with the determination of a set of routes (starting and ending in depots), each assigned to a single vehicle, in order to satisfy all customer demands, respect all operating constraints and minimize costs. After Dantzig and Ramser (1959) and the other basilar work by Clarke and Wright (1964), in which an efficient heuristic was proposed to improve the previous approach, a lot of papers addressed several variants of the problem proposing a large number of models and solving methods. The great scientific interest in VRP is demonstrated by various review papers realized in 50 years of literature. In this sense, most relevant works were by Christofides et al. (1979), Magnanti (1981), Bodin et al. (1983), Christofides (1985), Laporte and Nobert (1987), Desrochers et al. (1990), Laporte (1992), Fisher (1995), Golden et al. (1998), Laporte et al. (2000), Toth and Vigo (2002), Eksioglua et al. (2009) and, focusing on VRP with Time Windows (VRPTW), Tan et al. (2001), Braysy and Gendreau (2005a, 2005b) and El-Sherbeny (2010). In VRPTW each customer must be served in an associated time window, that can be soft (i.e. violable paying a penalty) or hard (i.e. inviolable). This seems to be the most suitable model for MWRP, because of the time window associated to each breakdown, already discussed in this paper.

2.3 Inventory Control Problem vs. Spare Parts Inventory Control Problem

Kennedy et al. (2002) pointed out the conditions that make spare parts inventories different from raw material, work-in-progress or finished product inventories:

- the need for spare parts is dictated by maintenance policies (or breakdowns), rather than customer demand;
- reliability information is usually not enough for predicting failure times;
- part failures are often dependent;
- demands for a part are sometimes met through cannibalism of other parts or units;
- stockout costs are difficult to quantify;
- machines for which the spare parts were designed can become obsolete and be replaced;
- if the major unit of equipment is broken but the new units is expensive, it is preferable to stock equipment components than or better to repair, if possible, the broken unit.

The addressed problem become more complex considering a multi-location and multi-echelon system, where each workshop must have the spare parts inventory necessary to meet the demand coming from breakdowns. For instance, Kalchschmidt et al. (2003), Kranenburg and van Houtum (2009) and Tiacci, L. and Saetta, S. (2010) approach this problem for an industrial supply chain. In the specific problem of an assistance service network for freight transportation vehicles, workshops usually stock a full assortment of spare parts and, when an item is collected, its replenishment is suddenly ordered. In addition, some items can be on board, creating a mobile stock that should be monitored in order to efficiently manage the network.

3. Problem Statement

This paragraph lays down the foundations for further research about modelling the problem of designing an assistance service network for freight transportation vehicles. For this purpose, parameters, decision variables and objective function are discussed.

3.1 Parameters

At least, information about the following parameters should be collected, in order to realize a comprehensive model with realistic constraints:

- *workshop parameters*: location of eligible workshops, yearly fixed cost for electing and operating a workshop (including employments, training, equipments, workshop modifications, marketing, etc.), maximum inventory level available in workshops, maximum number of mobile workshops;
- *spare parts parameters*: required assortment, inventory holding cost per spare parts unit per year, obsolescence risk and cost;
- *mobile workshop parameters*: maximum spare parts inventory level available into mobile workshops, yearly fixed cost for buying (or equipping) and operating a mobile workshop, transportation cost per distance unit;
- *breakdown parameters*: location, time windows, service time, type of breakdowns, spare parts requirement, fixed cost per served breakdown;
- *service level parameters*: desired number of time units to reach breakdown location, percentage of road network that should be reached within a desired number of time units, required percentage of breakdowns to be served on-time.

3.2 Decision variables

As already stated, the considered problem integrates three sub-problems. Each sub-problem corresponds to specific decision variables:

- *WLP variables*: set of workshops to be elected and inserted in the service network, set of breakdowns to be allocated to a specific workshop;
- *MWRP variables*: set of breakdowns to be assigned to a specific mobile workshop, route to cover assigned breakdowns, spare parts inventory on board;
- *SPICP variables*: inventory level in workshops, order quantity, re-order point, re-order interval.

3.3 Objective function

A realistic objective function should include the following costs:

- total fixed cost for electing and operating selected workshops;
- total spare parts inventory holding cost;
- total fixed cost for buying (or equipping) and operating mobile workshops;
- total transportation cost;
- total cost of breakdown repairing service.

4. Conclusions

The problem of design an assistance service network for freight transportation vehicles has never been addressed in Operations Management literature, though real-life freight transport operations show that a quick and effective assistance service is crucial in order to guarantee competitive service level and cost efficiency. This paper pointed out several analogies between the considered problem and other most famous problems in the research fields of Distribution Network Design and Emergency Medical Service. Most relevant works in these fields were reviewed, aiming at comparing different approaches and discussing modelling issues. This comparison showed that there are no models that can fit with considered problem. However, models and solving methods for Location-Allocation Problem (and the specific case of Ambulance Location Problem), Vehicle Routing Problem and Inventory Control Problem seem to be interesting starting points for addressing, respectively, Workshop Location Problem, Mobile Workshop Problem and Spare Parts Inventory Control Problem. In addition, a large number of papers focused on integrated models, showing advantages of combining location, routing and/or inventory decisions. This critical review allowed stating the problem from an integrated point of view, through the identification of parameters, decision variables and objective function, laying the basis for further research.

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