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Estimating the Vehicles' Number for Servicing a Flow of Requests on Goods Delivery

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Abstract

The paper presents an approach to estimate the number of vehicles used while servicing the requests for cargo deliveries. A problem of determining such a number of lorries that provides the maximum profit of a transport company with the maximum level of the clients' service is quite a complex issue due to the stochastic nature of the transport process and the random nature of the demand for cargo deliveries. The author presents a mathematical model of the transport process; on the basis of this model, the simulation model implemented in Python for the technological process of the flow servicing is developed. The results of the simulation experiment, based on the proposed software, allowed the author to determine the functional dependence of a level of service on parameters of demand and the number of vehicles. Using the obtained dependence, a formula for estimating the optimal number of vehicles was established as an argument, in which the function of the transport company's profit reaches its extreme maximum.

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Keywords: vehicles' number; requests flow; cargo delivery; stochastic demand

1. Introduction

A task of determining the optimal quantity of productive resources is one of the most significant problems in the operational management. The methods of solving this problem should consider features and goals of the production processes. As a rule, these processes has random characteristics due to a number of outer influences caused by the environment.

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For transport companies, the vehicles should be considered as productive resources, and the transport process – as the main production process. A process of transportation is completely stochastic, as it is conducted in the random environment of a transport system. In addition to stochastic nature of the main production process, demand for services of contemporary transport companies is also characterized by random parameters which influence characteristics of the process of transportation. The considering of all stochastic parameters leads to high complexity of any analytical model of the transport process. Thus, the most appropriate way to solve the problem of estimating the optimal number of vehicles is to develop a simulation model which considers stochastic parameters of demand and the transportation process.

This paper has the following structure: in the second part we provide a short review of recent publications in the field of modeling the transport processes to solve optimization problems related to the number of vehicles; in the third section the proposed mathematical model of a transport process is presented; the fourth part contains results of a simulation experiment conducted in order to estimate a functional dependence between the level of the requests flow service and the number of vehicles used for its servicing; the fifth section presents a model for estimation of the optimal number of vehicles obtained on the basis of the conducted experiment results; the last part contains conclusions and directions of future studies.

2. Literature review

Although the number of servicing mechanisms is key feature of a company providing services, the number of vehicles of a transport company is usually considered as one of additional parameters or goal functions for solving optimization problems.

Principally, the number of vehicles is used as an objective function in different types of a vehicle routing problem (VRP); it was considered in the papers of Islam and Rahman (2012), Ruttanateerawichien et al. (2014), Lysgaard and Wøhlk (2014), Sripriya et al. (2015), Gee et al. (2016), Sethanan and Pitakaso (2016). But also there exist other examples of optimization problems where the number of vehicles is used: the vehicles' number is considered by Wang and Li (2010) as a goal function to be minimized while solving a problem of loading the multi-category goods, the number of vehicles of different types is determined by Loxton et al. (2012) to solve a stochastic fleet composition problem, Wen et al. (2016) minimize the number of vehicles in order to solve a vehicle scheduling problem.

The number of vehicles is usually proposed to be used as an objective function together with the total traveling distance; this combination of the goal functions is considered by Islam and Rahman (2012), Ruttanateerawichien et al. (2014), Sripriya et al. (2015), and Wen et al. (2016). There also other combinations could be found: Loxton et al. (2012) determine such the number of vehicles so that the total expected cost of operating the fleet is minimized, Lysgaard and Wøhlk (2014) propose to investigate the effect of modifying the number of available vehicles in order to minimize the sum of arrival times at the customers, Sethanan and Pitakaso (2016) consider the number of vehicles together with the total costs of servicing, Gee et al. (2016) formulate the total traveling distance, the total driver remuneration, the number of vehicles used and the difference between driver remuneration in the multi-objective optimization perspective.

The choice of a mathematical method used in order to define the number of vehicles depends on the problem to solve: Wang et al. (2010) solve the optimal loading problem with the multi-ant colony algorithm, the ant colony algorithm is also used by Islam and Rahman (2012) to solve the VRP with time windows, the same problem is solved by Sripriya et al. (2015) with the help of the genetic algorithm, Ruttanateerawichien et al. (2014) propose the golden ball algorithm for solving the capacitated VRP, Lysgaard and Wøhlk (2014) solve the cumulative capacitated VRP with the help of branch-and-cut-and-price algorithm, Gee et al. (2016) developed the decomposition-based multi-objective evolutionary algorithm to solve the VRP with stochastic demands, Wen et al. (2016) propose an adaptive large neighborhood search heuristic for the vehicles scheduling problem. Each of the listed approaches for solving the optimization problems has its advantages and disadvantages explained by the authors. In this paper, we're going to develop the basic simulation model which could be expanded by methods appropriate for solving respective problems and to propose a variant of this model for estimating the number of vehicles.