IATSS Research 36 (2013) 123–128

Contents lists available at SciVerse ScienceDirect

IATSS Research

Improving the efficiency of weigh in motion systems through optimized allocating truck checking oriented procedure

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ARTICLE INFO

Article history:
Received 29 March 2012
Received in revised form 1 August 2012
Accepted 23 August 2012

Keywords:
Location
Axle load control
Weighing facilities
Road transportation
Enforcement

ABSTRACT

In the present paper, an effective procedure is proposed to determine the best location(s) for installing Weigh in Motion systems (WIM). The main objective is to determine locations for best performance, defined as the maximum number of once-checked trucks' axle loads and minimizing unnecessary actions. The aforesaid method consists of two main stages, including solving shortest path algorithm and selecting the best location for installing WIM(s). A proper mathematical model has also been developed to achieve objective function. The number of once-checked trucks, unnecessary actions and average installing costs are defined as criteria measures. The proposed procedure was applied in a road network using experimental data, while the results were compared with the usual methods of locating enforcement facilities. Finally, it is concluded that the proposed procedure seems to be more efficient than the traditional methods and local experts' points of view.

1. Introduction

Trucks' axles load control is one of the most essential issues in road transportation to prevent damage to infrastructures and improve road safety. Road infrastructure designs are based on permitted axle load and truck axle configuration [1]. If trucks' axle loads exceed the permitted ones, road surfaces will be deformed and considerable budget costs are required to repair them. On the other hand, trucks with excess axle loads, i.e. overloading, results in reduction of the reliability of trucks' braking system, increasing the stop distance and eventually increasing risk factors in road safety. Therefore, approved regulations exist on controlling axle loads to prevent infrastructures' damages and improve road safety [1].

It is vital for decision makers to know where to locate the systems used for axle load enforcement. In general, selection of enforcement devices sites is largely related to the links of high traffic volumes in the road network. This is no longer appropriate for installing WIM(s), because it rarely occurs that, axles' loads changed during the trip from origin to destination. So checking each truck only once would be more cost-effective method due to budget constraints. It is very important to install the WIM(s) in optimized locations to achieve the maximum number of checked trucks.

Location allocation is a common problem in transportation, rescue services [2], improving accessibility to road health services [3], electrical and electronic waste treatment [4], and in other fields of engineering sciences. A number of mathematical models have also been developed to locate road facilities. Most of them, used in location problem, consider conflicting criteria [5] due to the nature of problems. For example, Masood et al. [6] proposed an integer goal programming model to locate the fire stations in the city of Dubai using some tangible and intangible criteria. They considered some technical and political issues in the process of modelling along with travel time and distance, while cost-effective studies were also considered in their model. Chan et al. [7] offered a method to solve the problem of locating signal stations to receive the sent signals by at least three stations. They developed a multi-objective integer programming model and showed that their model is more appropriate than heuristic methods, which design the stations by random locating and local search, to locate the signal stations. Perriera et al. [8] managed a comprehensive survey of mathematical models used in locating the winter maintenance facilities. He concluded that four levels of problem, including strategic, tactical, and operational level, and real-time control are required to be considered for routing vehicles modelling and locating the road winter maintenance stations. Shetwan et al. [9] also studied the models used in allocation of control stations in multistage manufactures and showed that the most common techniques, applied in problem solving are considered as integer and dynamic programming approach.

Some practical studies are available for ranking the areas or candidate links for the establishment of road transport facilities. Portugal et al. [10]

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Peer review under responsibility of International Association of Traffic and Safety Sciences.

Production and hosting by Elsevier

0386-1112/$ – see front matter
http://dx.doi.org/10.1016/j.iatssr.2012.08.002

presented a procedure for realizing and ranking the candidate areas for building truck cargo terminals in Brazil. Kanaroglou et al. [11] developed a model to locate air pollution monitoring systems and showed that it is not necessary for locating air pollution monitoring systems in the areas with the high volume of traffic. Wang et al. [12] studied the problem of locating passenger refuelling stations, considering the economic issues together with higher services for inter-city trips. In another study, Wang et al. [13] studied locating road-vehicle refuelling stations based on the vehicle-routing logics using the matrix of origin–destination pairs. Their results demonstrate that larger vehicles are regarded more appropriate, need fewer stations, so they advise factories to pay more attention to larger vehicles. Laport et al. [14] solved the problem of locating stations in rapid transit lines, aim at acchieving the best coverage. Maximizing the coverage of prefixed stations was the objective function, while longest path type algorithm was used in model analyzing. Pierre [15] studied the problem of optimally locating rail-road terminals for freight transport and showed that the location of rail-road terminals has a significant role in rail transportation and terminal location would provide consequences on the entire European transportation system.

Two-step procedure of problem optimization is observed in the literature. Zhang et al. [16] presented a two-level procedure for space storage allocation in container terminals. At the first level, the total number of containers in each storage block and time period of the planning horizon is set to balance two types of workloads among blocks, at the second level, the number of containers associated with each vessel that contains the total number of containers in each block in each period, is determined in order to minimize the total distance to transport the containers between their storage blocks and the vessel berthing locations [16].

2. Scales and Weigh in Motion (WIM)

There are two types of static and dynamic scales used in the process of controlling axle loads. Using the static type, trucks must be stopped for checking. However, in the second one, the weights of truck axle loads are measured when the trucks pass over the scale [1]. One of dynamic systems is named weigh in motion, used to measure the weight of truck axles when trucks pass over the installed sensors in the pavement at high speed with the predefined accuracy [17].

Weigh in Motion (WIM) is a system equipped with an ability to measure the axle loads of vehicles, while trucks pass over installed sensors. Sensors are put beneath the asphalt layer surface to measure the amount of axle loads. Overloading is then detected based on data classification and axle configuration [17]. In the case of overloading, a picture of the vehicle is captured by a camera which is activated by the main part of system using sensors' data and analyzing axle loads based on authorized weights. The gathered data are normally transferred through a fibre optic device to the closest stop station and the vehicle is checked with high accuracy devices [17].

3. Problem definition and illustrative example

It is considered usual if transport decision makers locate the measuring facilities such as static scales or speed camera in the links with high traffic volume. Traditional practices have been considered to locate some control devices such as speed cameras in links with higher probability of over-speeding. This cannot be a good strategy for checking trucks' axle loads, because the amounts of them are rarely changed during the trip. Consequently, checking once is enough. The following example illustrates that selecting link with the highest traffic volume is not the optimum solution for installing the axle load measuring scales.

Assume that the road network G consists of 9 nodes and 10 links, shown in Fig. 1. As it is shown in the figure, the supplies of freight transport, measured by the number of trucks, are 150 and 450 for the origin nodes of 1 and 2, respectively. Demands of destination nodes are assumed by 100 and 500 for nodes 8 and 9, respectively. The link distance between nodes is shown as a number without parentheses beside each link. Shortest path technique is used to select the paths to carry goods to destinations and the results are shown in Table 1. The number of trucks calculated after solving the optimization model is placed beside each link in parentheses in Fig. 1. To further clear the case, note that the distance between nodes 3 and 6 is 75 km and the number of trucks planned to be passed on the link is 150, so the comment 75 (150) is placed beside link 3–6.

4. Defining the procedure

Solving the problem consists of shortest path algorithm and selecting the best location for WIM(s) simultaneously. A clear process has been utilized to simplify what might seem as difficult process. This process and the proposed model consist of the three following main stages, described more in the next sections:

1. Filling out the origin destination matrix using shortest path algorithm
2. Developing a mathematical model to assign WIM(s) to links
3. Running model and comparing results

The first step is to calculate the number of trucks passing over the links during the time study, which is considered as a year in this research work. In this step, the origin–destination matrix is filled out based on the results of running shortest path algorithm for all origin–destination pairs together with due supplies and demands. In the second step, a mathematical model has been developed considering the problem concept, i.e. checking axle loads of trucks once, should be maximized which results in the minimization of unnecessary checks. It guarantees that the checked trucks will be maximized considering budget constraint. Finally, the third step compares results with the previous method of selecting links and the views of local experts. Fig. 2 presents the overall background of procedure, including all above-mentioned stages.

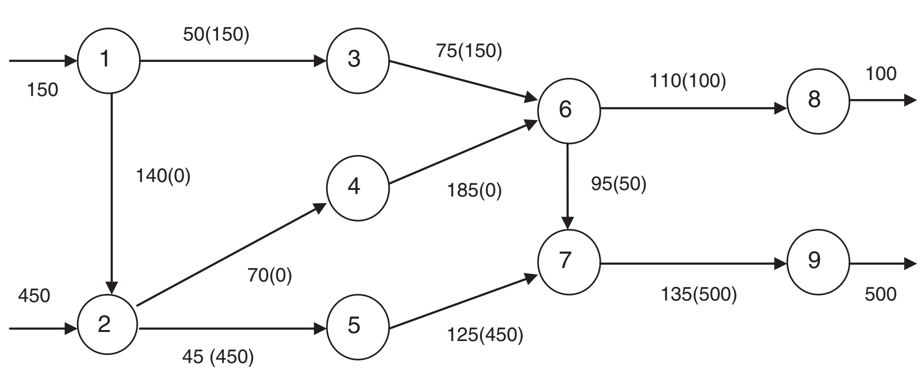

Fig. 1. Road network corresponding to illustrative example.