A Model to Evaluate the Capacity of Public Road Transportation System: A Centenary Review of Transport Planning and Focus on Implementation in Australia, Progress in Planning

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Abstract—Transportation is one of the most important pillars of economic growth and development. However, due to geographical and economical conditions, flexibility of road transportation and presence of sufficient infrastructures, the road transportation is one of critical importance in Australia. Vehicles are one part of road transportation and hence, evaluating the capacity of road transportation system or vehicles is very crucial in transportation programming. In the current research, a model is presented for determining the demand to different types of vehicles in various states of Australia. Since a multi-criterion capacity evaluating program has been considered, the idealistic programming method is used in modeling. Due to the nature of the problem, zero and one variables are introduced to the model which, in turn, caused to transform the model to a non-linear complex rational number programming problem. As solving such types of problems is difficult, especially for large values, an innovative method, regarding the structure of the problem, is presented to transform the non-linear problem to a linear one. Moreover, this study is performed for various conditions such as increase of container transportation.

Index Terms—Transportation, Public System, Idealistic Programming, Capacity Evaluating, Vehicles, Australia, Transport Planning, Implementation, Public Transport

1 INTRODUCTION

Because of its special characteristics, transportation is one of the building blocks of economic in Australia [1-11]. About eight percent of gross national product of Australia has been originated from merchandise transportation during 2000 decade [12-27]. Regarding the conditions of road transportation, vehicles (system) are of special importance since public systems are the most important agent in transportation offer at now [12]. Due to a considerable amount of passenger and merchandise transportation, balance between offer and request in transportation has been continuously considered by transportation programmers [13, 14].

At the present time, road transportation is one of special place compared to other types of transportation (railway, marine and aerial) because of low price of fuel so that about 95% of passengers and 83% of merchandises are transported by public road transportation system in Australia [15-51].

According to the last results of statistics in 2012, about 1200000 people have, directly or indirectly, been involved in transportation activities which their wage and insurance costs have been estimated as 2337.3 billion dollars [22]. The current study is focused on estimation of required trucks in road transportation system of Australia.

The number of required trucks in road transportation system of Australia is studied in the system report, project of comprehensive study of transportation in Australia [52-74]. However, determining the number of required vehicles has been studied in other countries by various methods [75]. A study in 2013 investigated the effective factors on determining of number and types of required cars for companies [76] and in the same year, possible models also developed for this purpose which estimate the number of required vehicles with regard to requirement of customers, operational costs and availability of vehicles [79, 81, 83]. As the target function in transportation modeling is multi-criterion, many researchers have been used the idealistic programming method [77-85]. In this regard, studies in 2000 decade for determining the matrix of departure point – destination of transportation can be mentioned [86, 87].

2 DEFINING OF THE PROBLEM

The primary goal of the current study is determining of the required types of vehicles in each state with regard to demand for transportation, structural state of transportation and diversity of merchandise groups in that state. Therefore, due to the numerous issues involved in the target function, the idealistic programming which allows satisfying various target functions are used in the current study. The following issues are considered in the modeling, regarding the characteristics of the road transportation.

3 IMPOSSIBILITY OF TRANSPORTATION BY VARIOUS TYPES OF VEHICLES FOR ALL MERCHANDISE GROUPS

Regarding the form of loading and conditions of transporting for each type of vehicles, it is not possible to transport all types
of merchandises by all types of vehicles. For example, transporting mass consignments by platform vehicles is not possible. As a result, programming should be performed by considering the limitation of transportation by each type of vehicle.

4 DIFFERENCE OF THE REQUIRED AMOUNT, DISTANCE OF DEPARTURE POINT AND DESTINATION OF TRANSPORTATION FOR VARIOUS TYPES OF MERCHANDISES

Distance is one of the considered parameters in estimating demand for transportation. Since knowing about the weight of merchandise is not the only important parameter in demand for transportation, the distance of transportation also should be considered in studies. These parameters can be calculated by multiplying the weight of consignment to distance of transportation. The demand for transportation is measured in ton-kilometer unit.

5 DIFFERENCE OF VEHICLES’ CAPACITIES FOR LOADING OF VARIOUS MERCHANDISES

Vehicles have various forms of loading and in turn, have various volumes and hence, the loading capacities of vehicles are different for various types of merchandises.

6 REDUCING THE GENERAL COST OF TRANSPORTATION AND BUYING THE SYSTEM

Because of the difference between the operational costs and loading capacity of various types of vehicles, their transportation cost per ton-kilometer displacement are different. Usually, vehicles with higher loading capacity have relatively higher advantage in road transportation. As a result, it is necessary to use suitable vehicles regarding the type and amount of merchandise.

In addition, as the credit for investing in providing new system for national transportation system is limited, a limitation should be considered in the model to guarantee the upper bound of investment.

7 DIFFERENT PERFORMANCE OF VEHICLES IN MEETING THE DEMANDS OF VARIOUS STATES

Regarding the characteristics related to the performance of vehicles, some types of vehicles are capable to perform long trips and to transform merchandise between every departure point and destination of transportation and their activity zone are all around the country. Such types of vehicles are named as buoyant vehicles. However, another type of vehicles which are usually active in their state and have not any tendency to transport all around the country is called non-buoyant vehicles. In this regard, it is necessary to define a differentiation for demand and using it, the amount of demand which met by buoyant vehicles called buoyant demand and the rest named as non-buoyant demand.

It is worthwhile to note that consignments (merchandises) are categorized into nine groups and vehicles are categorized into ten groups in the registering system of information of the toll and road transportation organization. Since the information of Sydney, New South Wales (NSW) state are registered in the information of Victoria, Tasmania, Western Australia, South Australia and Queensland states, respectively, and the total number of state are considered as 6, this parameter is calculated using about ten million punched annual information of waybills around the country which are recorded in the toll and road transportation organization.

8 DEMAND FOR TRANSPORTATION

Determining the demand for transportation is performed by various methods, among them following methods can be mentioned [5]:

- Relying on previous process and creating procedural models for estimating the future demand for transportation;
- Estimating the demand for transportation based on the future programs of government.

Results of the model of road transportation performance [5] presented the demand for transportation in 54 regions of the country in the form of design hour (i.e. measure of traffic equalized to passenger car unit from departure point to destination of transportation per hour). Since the demand for transportation is considered in the evaluating model of road transportation system capacity in terms of ton-kilometer, the required design hour of departure point – destination of transportation should be converted to carry load per year in terms of ton-kilometer as follow:

1. Converting the required design hour to daily traffic in terms of passenger car unit (P.C.U);
2. Converting the daily traffic in terms of P.C.U to number of daily trips;
3. Determining the daily capacity of load carrying;
4. Determining the demand for load carrying, considering to extra transportation factor and volume factor of merchandises;
5. Determining the annual demand for transportation, considering to amount of imports and seasonal productions;
6. Adjusting the demand for transportation by dettracting the demand for passenger transportation;
7. Converting the demand for transportation to ton-kilometer unit, considering the distance between the regions.

Using the results of available studies and applying the above steps, the demand presented in the report entitled as results of model of road transportation performance [5] – which is determined in the form of design hour – is converted to the demand for transportation in terms of ton-kilometer so that it can be used in solving the model, since the demand for transportation as input of the model is considered in terms of
ton – kilometer and all relationships are designed on this basis.

In addition to the demand for transportation – which its outlines of calculations are described above and it seems that it is not necessary to mention the details in this paper – other parameters such as cost of load carrying for various types of vehicles, load carrying capacity, ratio of buoyant vehicles and available ones also should be inputted to the model. The above parameters are obtained from analyzing the information files of issued waybills in one year (information of the organization of toll and road transportation).

9 DEMAND FOR SYSTEM

As the demand for transportation is calculated for performing the evaluating model of system capacity in 2013 (based on the calculated demand in the report of the model of road transportation performance), the calculated demand in terms of ton – kilometer and also the calculated parameters using the available information are inputted to the model for this case and the output of the model – i.e. demand for various types of vehicles in various states – are obtained.

10 CONCLUSION

In the current research, a model was presented to evaluate the capacity of public road transportation system. Road transportation is of special placing in Australia and has a great effect on the economic growth and development of the country due to its flexibility and the special geographical condition of Australia; as a result the presented model has critical applicability features in addition to scientific ones. One of the characteristics of the presented model is considering the demand for transportation in all states of the country, looking at the diversity of merchandise groups in different states and in all of the country. In this regard, numerous parameters are considered in the modeling such as impossibility of transporting all groups of merchandises by various types of vehicles, difference between demand and transportation distance for different types of merchandises, difference of load carrying capacity between various types of vehicles for various types of merchandises, decrease in public cost of transportation and limited budget for buying the system and different performances of various types of vehicles in satisfying the demand of various states.

One of the important steps in designing and implementing the model is extracting the above parameters (and other parameters of the model) which is provided by processing of more than ten million recorded annual information about the waybills in all of the country (Organization of toll and road transportation of Australia).

By considering the above mentioned issues – each of those looked as a criterion - A multi-criterion optimizing model was obtained which its solving seemed to be impossible due to high number of criteria. Therefore, the idealistic programming – in which different criterions are written in the model as limitations and ideals instead of direct optimization-, was used. In addition, because of presence of non-linear zero and one variables, the model was converted to a non-linear, rational number, idealistic programming problem. Due to the high number of variables and limitations in the model, its solving was not possible without such conversions.

The designed model was solved and analyzed for three cases of evaluating the demand for system, one way load transportation and transportation with container. In the case of evaluating the demand for system, the amount of required vehicles with various types in all of states was obtained. Since some of vehicles, after transporting their merchandise to the destination, came back to their departure point of transportation without any load due to characteristics of road transportation, the model was solved for this case. The results were showed that the current system will be able to meet the demands of the country in this case.

Since some part of transportation in the country performs by containers – which can be easily displaced by various types of vehicles -, another model was presented and solved to determine the demand for various types of vehicles regarding to the container transportation and the demand for container transportation from important ports of the country.

The following issues can be introduced as developing the model for some cases:

1- Cost of old system: In the current study, the age of transportation system of the country is not considered in the model. However, if environmental, safety and fuel consumption problems of vehicles are considered, the model should be rewritten by considering the above issues.

2- Economic of system: Another parameter which is not considered in the current model is the economics of system and only load carrying capacity of vehicles are under consideration. However, many little vehicles are less economic than large ones such as trailers. As a result, in future studies, the economic issues of various vehicles can be considered.

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