Optimizing transportation infrastructure planning: Koya city as a case study

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Abstract

In this article the feasibility of using a multi-objective genetic algorithm model to optimize land use, infrastructure, social, and financial variables has been investigated using multi-objective algorithm model. The model used in this article considered three primary objective functions which are minimizing travel time, minimizing per capita cost, and minimizing land use change.

Genetic programming is a further extension to the complexity of evolving structures within the genetic programming system the structures hierarchical computer programs. The size, shape and structure of the solution as a genetic program are left unspecified and are found by using genetic programming operators. Solving a problem therefore becomes a search through all the possible combinations of symbolic expressions defined by the programmer.

The model was applied on the Koya region in Erbil; a medium sized region experiencing rapid growth. The current population is 90,000 and projected to grow to 250,000 by the year 2030. Residents are becoming progressively more upset with new land development and increasing traffic congestion.
Keywords: genetic algorithm, land use, infrastructure, transportation planning.

1 General

By the late 1960s, transportation planning could no longer be performed effectively using only a single-project philosophy. Thus the systems approach emerged as the best way to solve multifaceted problems of this complexity.

The objectives of future planning for high-growth cities are many. One objective that the public is particularly sensitive to as a city experiences rapid

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growth is the minimization of traffic congestion. As more and more land is developed and spread out becomes more entrenched, the public desire for the preservation of open spaces increases. Other objectives include:

a. Controlling air pollution;
b. Providing affordable housing;
c. Maximizing economic development;
d. Minimizing taxes and fees;
e. Preserving historical and cultural sites;
f. Providing adequate utility infrastructure;
g. Minimizing change;
h. Providing adequate education;
i. Providing adequate public safety.

The cyclic interaction of transportation facilities and land use is shown in Fig. 1 [1]. Land use has found to be the prime determinant of trip generation activity. The level of trip generation activity and the orientation of trips within the study area will determine the need for facilities. Provision of these facilities alters the accessibility of the land itself, which in turn helps determine to potential use of land. Since potential land use is the major determinant of land value, the planner had faced with a cycle in which alteration in any one element causes both to all other elements and to itself.

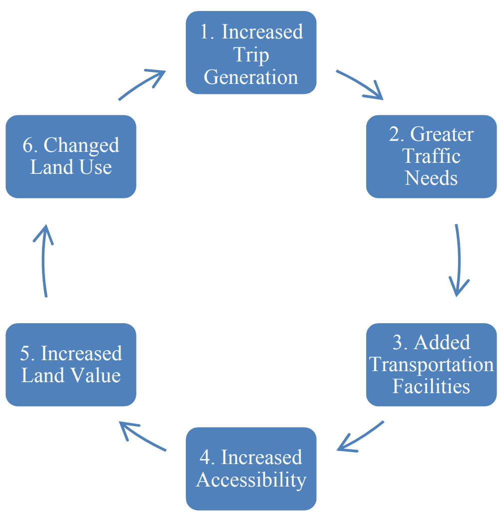

Figure 1: The land use transportation cycle.

2 Types of planning

Transportation planners find themselves involved with two different types of planning: short- and medium-term or long-term (strategic) planning.

Of these two, *short- and medium-term transportation planning* is usually far less complex. By its very nature; this type of planning tends to place no great demands on construction activities and therefore has no large capital requirements. Short- to medium-term planning is concerned with obtaining maximum capacity or optimal operation from existing facilities. As such, in the analysis and evaluation stages, the planner is dealing with a limited number of criteria. In proposing solutions, the number of options is likely to be limited and the planner usually is constrained to options that are totally contained within the budget allotted to transportation. Therefore, the scale of the problem usually is quite limited and the analysis evaluation, while being detailed, are usually simple in structure. This type of problem comes under the generic term *transportation systems management* (TSM) [2, 3].

Long-term, comprehensive, or strategic transportation planning, on the other hand, can be and is likely to be a very complex problem indeed. This type of transportation planning will require huge financial expenditures and involve large and extensive construction programs that will affect the economic, social, and natural environments. Furthermore, the desired solutions can be achieved only through carefully constructed policy-making at the multiply levels of government and administration involved [4, 5].

There are seven principal models used in the process of long-term planning:

a. Population model;
b. Economic activity model;
c. Land use model;
d. Trip generation model;
e. Trip distribution model;
f. Modal split model;
g. Traffic assignment model.

3 The land use in transportation model

The land use in transportation model can be dividing into two distinct phases: the calibration phase, in which the models are built and tested using data from a base period, and the projection phase, where the developed models are used to determine future transport demand based on socio-economic projections for a design year.

Population and economic activity predictions generally are derived by specialist demographic and economic projections outside the scope of the transportation study. Because these areas usually would not require detailed examination by the transportation specialist in the preparation of the typical long-term transportation plane, they are omitted from this discussion.

There has been considerable debate on the third of these seven models, which for determining land use. A number of models have been developed that relate changes in land use to such independent variables as:

a. Accessibility to employment;
b. Percentage of available vacant land;
c. Land value;
d. Intensity of land use;
e. Measures of zone size;
f. Amount of land in different uses;
g. Net density of development in the base year;
h. Employment by land use type;
i. Time and distance to highest valued land of study area;
j. Degree of zoning protection expressed on a quantitative scale;
k. Transit accessibility;
l. Quality of water and sewer service.

Some of the dependent variables that have been predicted include:

i. Increase in residential units;
ii. Increase in commercial land use;
iii. Increase in industrial land use;
iv. Increase in retail land use.

A number of models have been built, some of which have extremely sophisticated and capable of calibration to remarkable accuracies. These models are based on the interactive nature of the supply of development infrastructure and urban growth. There is, however, a very strong case against using land use models entirely for predicting urban growth. If used, the resultant land use plan will be self-fulfilling and the growth obtained is likely to be similar to that predicted by the model. However, the combination of the land uses achieved may not be desirable. Many planners feel that the layout of land use is vital to the proper development of any community and strongly resist any attempt to have this basic planning input modeled. In areas such as Europe where is strong planning legislation, the land use pattern is set out by planners who design the development of communities with conventional design procedures. Land use modeling may be used, but only in the broadest sense, to ensure that adequate space has been supplied for each type of land use on a community wide basis. Modeling of zonal changes would not be used in this case. On the assertion that land use models have not proved generally applicable in the land use transportation modeling process, there is no need for further discussion of this topic. In summary, transportation planners generally are given land use plans where density and type of land use are set by design consideration rather than by modeling outputs.

The four remaining models are of considerable interest for strategic transportation planning: *trip generation, trip distribution, model split, and traffic* *assignment*. The planning area is dividing into a number of relatively homogeneous traffic-generating zones. The total traffic flow has modeled by treating the traffic as generated by the center of gravity of each zone and moving between and within zones over the principal transportation network. Conventionally, the models are developing sequentially. Trip generation models indicate how many trips are generating in each zone for a particular journey purpose. Trip distribution models describe how many trips originating in one particular zone end in each of the other zones. Model split analysis models the proportion of trips that occurs to the various competing modes of transportation. Finally, the traffic assignment model indicates which individual routing will be taking by a trip between its origin and destination [6].

4 The research objective

The objective of this research is to optimize the infrastructure planning by using a multi-objective genetic algorithm models through minimizing travel time, per capita cost, and land use change of some regions in Koya City.

The model has applied to a region of Koya city, a fast growing community. Ideally, all combinations of land use, infrastructure, and social variables would be examine, however, even a small city of 200 traffic zones with an average of 10 land uses will over 200^{10} possible zoning alternative. A more efficient way to examine an extremely large search set of feasible designs is to employ artificial intelligence techniques to quickly narrowing the number of alternatives to be considering.

5 Scope

The city of Koya is a medium sized city experiencing rapid growth, and divided into four main traffic zones.

The research work zone includes two main stages, in the first stage, it was taken the map of traffic zones in Koya city and its estimated population, in the second stage, the roadway infrastructure had been shown as a critical set of decision variables. The real model of roadway facilities and potential capital improvements, it had decided to represent road facilities in corridors. This corresponds well to the MinUTP traffic network which has only includes roadway classifications of collectors and arterials (with a few key local roadways). A roadway corridor is assumed to have one cross-section type. Although in some real situations, this might not be the case, based on the experience of traffic engineering, this work to be a reasonable assumption.

Otherwise, it would be necessary greatly expand the number of variables and size of the GA genes.

A large number of constraints are used in the model to maintain realistic physical and social balance. Constraints include the following:

1. Housing must be in sufficient quantity to house the assume population according to current household size;

2. Housing types (size and cost) must be in proportions to each five income groups;
3. Revenues must equal or exceed expenses.

Plans do not meet constraints had to be thrown out. Each feasible solution has the objective functions calculated. Travel time is calculated from the MinUTP output by summing vehicle hours for each roadway link in the model. No level of service constraint is placed in the model since congested roadway links have accounted for by increased travel time on the respective links.

The Pareto sets was used to assess and determine the optimum of the large numbers of feasible solutions. To determine the Pareto set, a Pareto fitness function was utilized to develop the best solution for one objective, holding the other objectives constants.

6 Conclusions

Koya city has improvement in the account of vehicles and transportation through the ten years ago, so this account is increasing three times from 2003 to 2012. For this reason the streets in Koya city is not enough capacity to assimilate this amount of vehicles.

The improvement of the traffic signal times, the direction of cars movements, and redesign for land use had become necessary demands for Koya city with the additional reason which is presents by established the University of Koya and the new tourism centers and increased the movement from and to Koya city.

7 Recommendations

This study will involve:

1. Traffic volume study;
2. Speed study for the movement vehicles;
3. Land use study to prepare suitable garage areas;
4. Social study for the populations in Koya city;
5. Land use study for the markets and industrial areas;
6. Study of the connecting streets from the Koya city with the neighbor towns and villages;
7. Other matters will be necessary needs to cover through this study.

After all of these, it will be

a. New design of the traffic signals and established new traffic signal controls;
b. New design for the movement direction for the previous streets in Koya city now;
c. Suggested new streets will be constructed in the future.

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