URBAN TRANSPORTATION PLANNING USING PORTFOLIO PROGRAMMING

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ABSTRACT
Today, the necessity of public (especially urban) transportation systems is a known fact. So, it is of utmost importance to have a systematic understanding of and a basic planning, along with a quantitative improvement, for such systems. While variety of these systems (subway, monorail, tram, bus, taxi, etc.) makes their choice a difficult task for decision makers, it is quite possible to propose a suitable single or combinatorial system for any district or zone inside urban areas with proper planning and effective management. The main objective of this research is to present a method for coordination and integration of different transportation systems working in a metropolis. Effort has been made, in this paper, to determine an efficient frontier on the basis of which one can decide, at any service level, what the best combination of investment-development budgeting of each transportation system may be. We have tried, using the portfolio programming, to define and calculate the appropriate cost and benefit criteria for each public transportation system first and then determine the optimum development budget of each system based on the available budget.

Keywords: *urban transportation, portfolio programming, hierarchy analysis.*

1. INTRODUCTION

Transportation and traffic is, today, an important issue in metropolises urban management. In this relation, conducting and managing the public transportation has a great role in the smoothness of traffic and the citizen's peace of mind. Variety in public transportation systems, implementation limitations and budget restrictions for every public transportation system have always made decision making difficult for city management authorities. Making a decision on the selection of any of the systems has its specific consequences and risks. This is why some authorities make different and sometimes even contradicting- decisions during successive periods of making policies. The results are, therefore, scattered and inconsistent investments in different systems such that in a period of time most of the money is spent in subway systems, but before it is finished, the budget is shifted to other systems such as BRT, due to a policy change, and the previous one is left unaccomplished.

It is intended, in this paper, that a model be presented for the determination of necessary investment and budgeting for every different urban public transportation system. In this connection, the modeling of urban transportation investment is carried out with the help of "portfolio programming" and the related results are used in dividing the budget according to different service levels.

Markowitz and Sharpe [5], [10] are believed to be among the first people who introduced the concept of Mean-Variance (M-V) portfolio selection problem. Their models consist of a parametric quadratic objective function subject to some linear constraints. Hence, the portfolio selection problem is normally formulated as a convex optimization; and, in general, there are methods [3] to solve this class of problems. However, there are some special cases where we can determine a closed form solution from uncorrelated assets. Best and Hlouskova [2] have studied this problem and provided a closed form solution for two special cases. They have explained that the results of their solutions depend on the order of the expected returns of the assets. Sadjadi et. al[8] have presented an alternative closed form solution and discussed the details of the efficient frontier based on the explicit results.

To use portfolio programming, 3 parameters- service level, expected value of profit and standard deviation- are to be determined for different transportation systems. The expected value and standard deviation for every system are found using the hierarchical method.

AHP helps us capture both subjective and objective assessment measures of the alternative options available, thus reducing bias in decision making. AHP uses pair-wise comparisons which allow verbal judgments and enhance the precision of the results. The pair-wise comparisons are used to derive accurate ratio and scale priorities. Developed by Thomas Saaty [7], AHP provides a verified, effective means to deal with complex decision makings and can assist in identifying and weighing criteria, analyzing the data collected and expediting the decision-making process. AHP helps us capture both subjective and objective evaluation measures providing a useful mechanism for checking the consistency of the evaluations, thus reducing bias in decision making, [4]

This manuscript has been organized as follows: portfolio programming is presented in section 2, the methods to find the expected value and standard deviation for every transportation system using AHP, are given in section 3, model calculations are brought in section 4 and finally, conclusions are summed up in the last section.

2. PORTFOLIO PROGRAMMING

Portfolios have been used for years by architects, artists, and designers. A portfolio programming is a great way to show the best work. Portfolio optimization is widely used in finance in the formulation of mean variance optimization of investment decisions under uncertainties. The constraints are linear and the objective function is quadratic (Markowitz, 1959). The decision maker needs to reconcile the conflicting desires of maximizing the expected portfolio return, represented by the linear portfolio return term, and minimizing the portfolio risk, represented by the quadratic portfolio variance term, in the objective function.
Consider a portfolio selection of the following form:

$$\min\left\{-trx_0+\sum_{i=1}^{n}(-t\mu_i x_i+\sigma_i^2 x_i^2)\middle|\sum_{i=0}^{n}x_i=1,\ x_i\geq 0,\ i=0,\dots,n\right\} \qquad (1)$$

where $\mu_1,\dots,\mu_n$ and r are the expected returns of risky assets and that of the risk free asset respectively, $x_0,\dots,x_n$ are asset holdings (to be determined) and $\sigma_1,\dots,\sigma_n$ are variances of all n risky assets. The primary assumption in (1) is to preclude any short selling. In other words, all variables must be non-negative, i.e. $x_i\geq 0, i=0,\dots,n$.
Problem (1) can be solved for different $t\in(0,\infty)$. Let $x(t)$ denote an optimal solution of (1) for a given t, $\mu_p=trx_0(t)+\sum_{i=1}^{n}t\mu_i x_i(t)$ and $\sigma_p^2=\sum_{i=1}^{n}\sigma_i^2 x_i^2(t)$ too be also the corresponding mean and variance of the portfolio respectively. The plot of (σ_i^2,μ_p) for different $t\in(0,\infty)$ is called the efficient frontier.
Generally, when t in (1) increases, x_0 eventually tends to 0 for $t=t_m$ and the corresponding x is the market portfolio x_m. Problem (1) has been studied well [1], [2], [3].
Sadjadi et al. [8] have solved this problem by dynamic programming and reached the following optimal solution:

$$x_i^*=\frac{t(\mu_i-r)}{2\sigma_i^2} \qquad i=1,\dots,n$$

$$x_0^*=1-\sum_{i=1}^{n}x_i^*$$

3. PUBLIC TRANSPORTATION CRITERIA

As mentioned before, to use the portfolio programming, it is necessary that the expected value and the standard deviation for every transportation system be determined. Since every system has advantages in some and disadvantages in other aspects, we cannot directly find its expected value; first, we have to determine what the users criteria are and then study them in detail. We will now enumerate some basic criteria, taken from other studies, and divide them into two groups under “profit” and “cost”. The expected value and the standard deviation for every system may, then, be determined using the hierarchical process.

3.1. “Expected value” criteria

Urban public transportation expected value criteria are based on 3 researches carried out by Modesti and Sciomachen[6], Wang and Peng [11], Zak[12] and salavati et al.[9]. The most important criteria, introduced in these studied, are: crowd mitigation, safety enhancement, pollution reduction, travel time reduction and ease in travelling.

3.2. “Standard deviation” criteria

For these too, use was made of the aforementioned studies [6, 11, 12, 9]. Hence, we have selected those criteria that are of expense (cost) quality; they are: construction cost, indirect construction cost, traveling cost and indirect exploitation cost.
By indirect costs, we mean those imposed indirectly on citizens by transportation system. For example, the BRT system cause narrowness of road way- hence heavy traffic for the citizens; or, to construct subway system, it is necessary that some streets in the city be closed for a long time which is an indirect cost burden on the people.

4. TEHRAN CASE STUDY

Tehran, as one of the world’s metropolises, has been studied in this research. Hence, and for this purpose, we have investigated how the annual investment (budget) for urban transportation, being nearly 150 million dollars, is distributed among subway, BRT, bus and taxi transportation systems. Use has been made of 30 expert specialists for the determination of the “expected value” and “standard deviation” of the existing transportation systems. Since the AHP method and related table are known and available, they have not been brought in the manuscript; we have given only the latest tables related to every transportation system along with their related weights. Table 1 shows the direct matrix of different systems based on profit criteria and table 2 shows the decision matrix based on cost criteria.

Weight of criteria= (0.28, 0.11, 0.14, 0.35, 0.12)

	crowd mitigation	safety enhancement	pollution reduction	travel time reduction	ease in travelling
subway	0.43	0.32	0.5	0.39	0.35
BRT	0.3	0.27	0.29	0.34	0.25
bus	0.2	0.25	0.16	0.05	0.03
taxi	0.07	0.16	0.05	0.22	0.37

Considering tables 1 and 2 and the presented weights, the standard deviation and the expected value of every one of these systems can be summed and shown in table 3.

Weight of criteria= (0.3, 0.22, 0.34, 0.14)

	construction cost	indirect construction cost	traveling cost	indirect exploitation cost
subway	0.72	0.7	0.16	0.52
BRT	0.15	0.2	0.12	0.31
bus	0.08	0.09	0.07	0.1
taxi	0.05	0.01	0.65	0.07

We may now make use of relation 2 and find the optimum share of each system from the annual investment (budget).

	subway	BRT	bus	Taxi
expected value	0.4	0.3	0.13	0.17
standard deviation	0.5	0.17	0.08	0.25

Considering Tehran's performance during past few years, shown in table 4, it can be concluded the model is reliable. In instances where there are some differences, they can be balanced by minute analysis and experts view points.

	Subway	BRT	Bus	Taxi
Actual	0.38	0.18	0.24	0.2
Optimum share	0.41	0.19	0.21	0.19

5. CONCLUSIONS

In this paper, we wanted to determine the annual budget share of different urban public transportation systems using portfolio programming. To find the expected value and the standard deviation of each system, use was made of AHP. The proposed model was applied to the city of Tehran and the results, compared with those of real performance, were justifiable.

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