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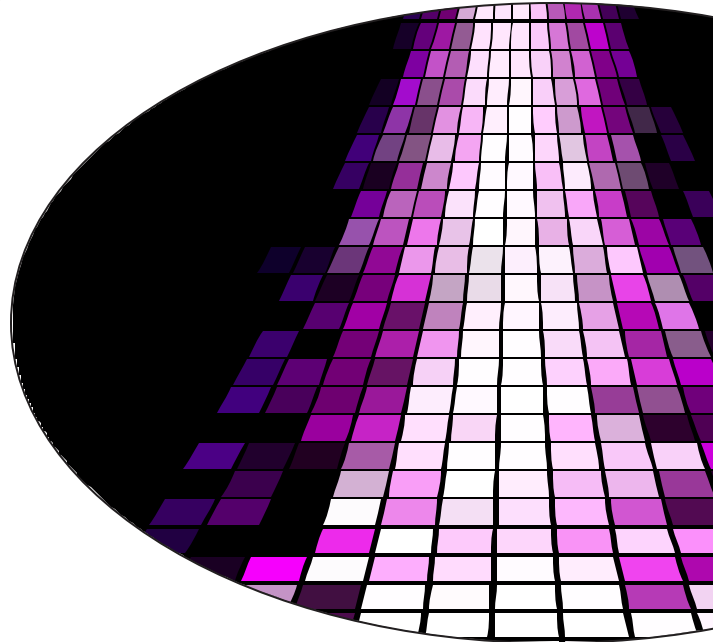
# Using the Genetic Algorithm for Optimization of the Integrated Urban Transportation Systems

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**Abstract**

*Improving the public transportation problems should rely on integrated multidimensional transport policies which can soften the demand of infrastructure investment. However, it would be very difficult to fully consider the multi-dimensional transport polices in planning framework because there would be too many possible policy combinations to be evaluated. So, this study attempts to develop an analytic framework for evaluating urban integrated transport policies comprehensively, including strategies of investment, pricing, management and regulation. To deal with the difficulty of too many policy combinations, genetic algorithms will be used to search for the optimal strategy combination for integrated transport strategy. Finally, the relationship between quantified objectives, policy combinations, and assessment performances would be analyzed using the proposed model.*

**Keywords:** *Multi- Demsional Transport, Genetic Algorithms, Pricing, Investment, Regulation.*

## INTRODUCTION

To develop sustainable transport in cities, the integrated transport policy should be fully considered in conjunction with land-use, socio-economy, environmental impact, finance and sustainability rather than restricting it to only a single policy element (Taleghani, 2006). Most of the constituent elements of these strategies are already available, but there is a serious lack of detailed understanding of the impacts of many of these policy instruments and of their transferability to different contexts (Taleghani, 2006). However, it would be very difficult to fully consider the multidimensional transport polices in transportation planning framework, because there would be too many possible policy combinations to be evaluated. Even more serious is the lack of understanding of how to design integrated strategies which most effectively combine infrastructure, management, regulation and pricing. Even where appropriately sustainable strategies are identified, there are serious barriers to their implementation (Taleghani, 2006). Therefore, only simplified policy combinations have

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been considered in the real world practices. Thus, this study attempts to develop an analytic framework for evaluating urban integrated transport policies comprehensively, including strategies of investment, pricing, management and regulation. For more reliable and realistic applications the evaluation framework should consider many factors, which increase the complexity of the problem. They are considered with different emphasis and levels of detail at different stages in the whole evaluation process. Hence, there is a need for new optimization method which takes into account the interdependency between these four elements for various levels of the designed goal or subjects. In this study, genetic algorithm (GA) approach has been proposed to search for the optimal strategy combination for integrated transport policy. In this paper we review the related literature and dilate on the simulated steps of the evaluation framework. Then, we discuss the policy instruments considered in addressing urban transport problems and the formulation of integrated transport policy alternatives. After that the paper outlines the optimal solution methods developed for the combined four different policy elements. Numerical analysis is also carried out here. Some conclusions for urban transport policy are drawn finally.

Integrated transport studies (ITS) are a base for guiding the development of transport strategy from 1990s. The concept of 'integrated transport' has become an important guiding principle for transport policies' institutional and structural development in many countries.

Its purpose is "to provide access to goods, resources, and services, while reducing the need to travel, so that economic, environmental and social needs can be met efficiently and in an integrated manner" (Potter and Skinner, 2000). May and Roberts (1995) have developed the resulting optimization procedure to evaluate the optimal Integrated transport policy combinations. Afterward, European Union had an OPTIMA project, for generating optimal transport strategies has been applied in nine European cities. The resulting optimization procedure is used to find out the optimal integrated transport policy combinations. Furthermore, the policy measures were tested using city-specific transportation models which had already been set up, calibrated and used by the city authorities before the star of the project (Timms et al., 2002).Those researches bring up a new way to update the traditional transport policy planning. According to different visions

of urban developed plans, planners conferred on the best way to integrate transportation and land-use policy instruments. Then, broad quantification of representative scenarios for transport was required covering national and local factors so as to provide a focus for the appraisal of alternative transport strategies by area, corridor and mode (Jones et al., 1990). Through quantitative analytical framework, the synergy between each policy instruments would be clarified. Offering a substantial and feasible planning process is so different from the blueprint or white book.Urban transport policy has had a significant development in the last decade with the emergence of a much wider range of policy instruments available to the urban transport planner. How to effectively categorize urban transport policies and strategies is a big challenge. World Bank (1986) divided urban transport policies into four parts, which are transport demand management, traffic management, public transport management, and infrastructure. The project Knowledgebase on Sustainable Land Use and Transport (KonSULT) (Matthews et al. 2002), has categorized instruments by type of intervention, distinguishing between six types: land use policies; infrastructure provision; management and regulation; information provision; attitudinal and behavioral measures; and pricing. Jones et al. (2003) tried to evaluate and implement transport measures in a wider policy context, and divided policy context into four parts, infrastructure, management, information and pricing. Through the review of urban transport policy discrimination, we obtain that infrastructure; pricing, management and regulation are important dimensions in urban transport policy.

## ASSESSMENT

A good integrated transport policy should throng a complete evaluation process before it becomes actionable for implementation. Therefore, we construct a comprehensive evaluation framework based on the travel demand forecasting for appraising integrated transport policy alternatives. The comprehensive evaluation framework will be detailed step by step. After that, the paper focuses on the city Kaohsiung, and follows it's urban long-term development plan, to define the context of the integrated transport policy alternatives. The paper also applies the genetic algorithm in terms of the systematic and automatic solution. Finally, we interpret the genetic algorithm parameters for the model application.The evaluation framework was originally proposed by Chen

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et al. (2005). An integrated transport policy alternative includes four different policy dimensions; investment, pricing, regulation, and management as shown in Figure 1. The number of policy alternatives were limited because the whole process could not operate automatically (Chen et al., 2005). There are three to five different strategies or instruments in each policy dimension. Each strategy under different policy dimension is difficult to identify in true quantitative content. For example, how to decide the parking fee per hour precisely is hard in pricing policy dimension, but it is an important simulation result which is required while making suggestions to the local authorities. Therefore, we modified the framework and applied GA optimization heuristic to deal with above shortcomings and tried to find out more quantitative and specific integrated transport policy alternatives in this modified evaluation framework (as shown in Figure 1).The modified framework is illustrated in Figure1 and starts with the vision of the urban area (Step1). Public transportation is a sustainable form of urban transportation (World Bank, 1996), and serves as a promising solution to the problem of transportation demand in most urban cities around the world (Wong and Lam, 2006). Therefore, in order to solve urban transportation problems, the main goal is to encourage people to use public transportation more frequently. Then, an explicit objective is to raise the public transport market share (Step2). The next step is to construct a combination of investment, pricing, regulation, and management to generate some possible and reasonable policy alternatives. The combinations themselves allow the interaction between four categories to be assessed (Step3).

Then, each alternative needs to analyze its travel demand in the future predicted year by the traditional classic four-stages of trip generation; trip distribution, mode split, and trip assignment (Step4). According to the results of the travel demand analysis, we can calculate the number of trips made in each traffic zone, and the percentage of market share in each mode. From the steps of the transport policy alternatives selection, the travel demand analysis, to the step of the alternatives evaluation, genetic algorithm has been proposed to search for the optimal strategy combination automatically. This mechanism also has the feedback function to check the degree of the transport goal implementation. After the iterations, the optimum integrated transport policy alternative can  appear automatically (Step5).
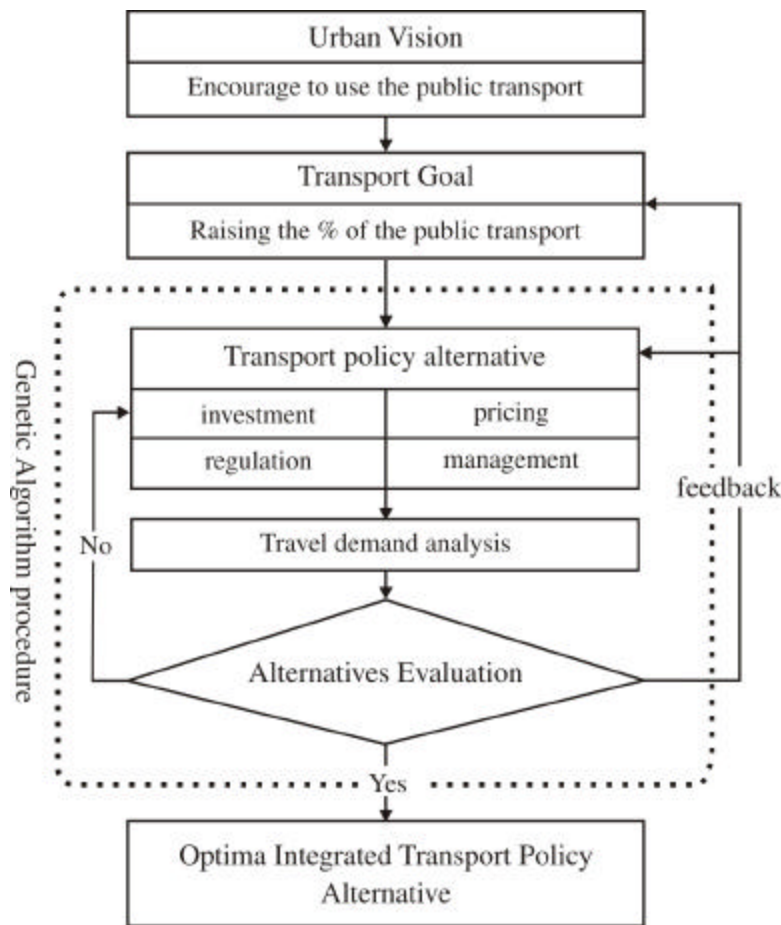
Figure 1: The Comprehensive Assessment Framework

## GA AND MODEL APPLICATIONS

Genetic Algorithms (GA) was first introduced by Adham (1975). GA imitates the principles of natural evaluation for parameter optimization problems (Michalewicz, 1999). It is a kind of simulation nature heredity search principle. Mainly it simulates Darwin's "the theory of evolution" as the calculation foundation. Using the nature heredity characteristic, GA contains several operators, reproduction, crossover, mutation and so on. Goldberg (1989) elucidated applications of GA and attracted the growing interest of optimization problems. GA is also a family of adaptive search procedures that are loosely based on models of genetic

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changes in a population of individuals (Holland, 1975). Goldberg (1989) states four important distinctions of GA over other search methods: a) GA works with a coding of the parameter set, not the parameters themselves; b) GA searches from a population rather than a single point; c) GA uses pay off (objective function) information, not derivatives or other auxiliary knowledge; d) GA uses probabilities transition rules, not deterministic rules. Besides, Holland (1975) discuss that the main advantage of GA is its ability to use accumulating information about initially unknown search space in order to bias subsequent searches into useful subspaces. According to the comprehensive evaluation framework (Figure. 1), Kaohsiung is selected as focal city for this empirical research because it is the second biggest city in Taiwan and has the biggest international commercial harbor. To find out the optima integrated transport policy alternatives, the GA flow is developed to carry out the detailed steps. The hypothesis explanation is as follows:

In order to optimize the objective function, we need to code the strategies with some precision. To present the entire integrated transport policy altogether, we design a chromosome V0 to include four sections of genes {x1, x2, x3, x4}, which separately express the strategy of investment, pricing, regulation and management.

The investment policy dimension {x1} designs five different public transport networks according to the long-term planning of Kaohsiung city government, (including exist road network) additionally constructs the MRT line; additionally constructs the LRT line; increase bus system; and reduces the headway of bus system. The pricing policy dimension {x2} is presented by different level of parking fee because Kaohsiung city has a serious parking problem by road side. The charge for parking fee may be divided into five kinds, because they rely on the different characteristics of traffic zones. The roadside- parking fee is 30 NTD per hour according to the Kaohsiung city transportation bureau (KCTB) . Some parking spaces are charged such that for every additional hour, extra money is added in the fee. For example, the first hour is 50 NTD, and from the second hours it increase to 100 NTD. Therefore, the research design for this paper considers the parking for automobile as 20 to 50 NTD for each hour, and for motorcycle from 0 to 25 NTD. The simulation range takes every 5 NTD.
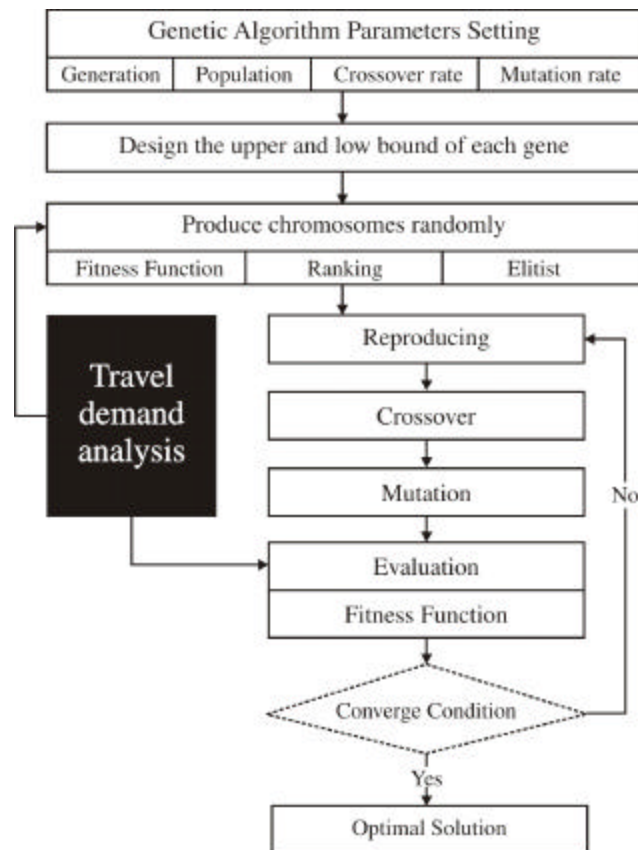
Figure 2: The Genetic Algorithm Process

The management policy dimension {x3} has many qualitative strategies, such as tax, toll, and out-of- pocket cost. Those strategies may be sum up in the traveling cost per kilometer by different modes. The traveling cost per kilometer is according to officially published report by the Ministry of Transportation and Communication. This research designs the traveling cost of vehicle owner for each kilometer from 2 to 9 NTD and the motorcycle for each kilometer from 1 to 2.5 NTD. Sampling for simulation will take every0.2 NTD as a unit.

The regulation policy dimension {x4} accounts the time for searching a parking space and walking to the destination. Five different kinds of time specifications are designed because each traffic zone has different parking space provision. The automobile searching time is 0 to 10 minute and the

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walking time 0 to 10 minutes. The motorcycle searching time is 0 to 10 minutes and the walking time 0 to 10 minutes. Sampling for simulation will take each minute as a unit. If we try to simulate all of the combinations, there would be more than thousand combinations and there will be a need to find out the optimum one. This is the reason for applying GA to raise the simulation efficiency. The initial population is the first generation of chromosomes. These are of two general common kinds, one is randomly produced that may retain the biggest variation. The other is randomly co-ordinated. A good initial population is helpful to the search efficiency, as it guarantees the result to be able to converge fast. This research produces the initial population randomly and each generation has 20 chromosomes. The fitness function plays the role of the environment, rating potential solution in terms of their fitness. In order to strive for the simplification, this research designed "the market share of public transport" through the travel demand analysis to take the fitness function, (evaluates fit and unfit quality of the chromosome). Because the travel demand analysis needs to simulate in another transport specific software, the design of fitness function is in an equation form or objective function, instead of a percentage numeric. Selection process is to select of a new population with respect to the probability distribution based on the fitness values. A roulette wheel with slots sized according to fitness is common used. Now we are ready to apply the recombination operator, crossover, to the individuals in the new population. The probability of crossover, (pc) is one of the parameters of a genetic system. This probability presents the expected number (pc*pop-size) of chromosomes which undergo the crossover operation. Mutation is performed on a bit-by-bit basis. Probability of mutation, (pm), another parameter of the genetic system, is used to calculate the expected number of mutated bits.

The model is performed with the following GA parameters:

Population size (n) 20
Generation number (t) 100
Probability of crossover (pc) 0.5
Probability of mutation (pm) 0.01

## THE SOLUTION ALGORITHM OF THE GA

*Step1* GA parameter setting: The important parameters of genetic system are population size, generations, probability of crossover and mutation.

*Step2* Design the upper and lower bond of each gene. For given lower and upper bond of the different strategy, represent the parameters as binary strings to form a chromosome.

*Step3* Generate the initial random population of the model parameters and set t=1.

*Step4* Decode all weighting variable to map the chromosomes to the corresponding real numbers.

*Step5* Calculate the fitness functions for each chromosome.

*Step6* Reproduce the population according to the distribution of the fitness function values.

*Step7* Carry out the crossover operator by a random choice with probability pc.

*Step8* Carry out the mutation operator by a random choice with probability pm, and then we have a new population.

*Step9* If the converge condition is reached, return the optimal solution; if not, go to Step6.

## NUMERICAL RESULTS

The transportation planning software (MINUTP) needs to operate under the DOS environment. Therefore the whole simulation procedure and algorithms are written in one batch file including three parts, known file input and output, transport requirement forecasting, genetic algorithm. Besides, to do the travel demand analysis we need some data collection and model assumptions in each step. Most of data needed in this analysis, was obtained from the transport planning reports and records of the Kaohsiung Rapid Transit Corporation (KRTC), and partly from the official annual statistical reports of the Kaohsiung City Government. Furthermore, the simulated year setting is from the base year 1997 to the situation in year 2010.Through the evaluation procedure, as described above, the change of public transport market share is illustrated in Figure.1. The urban vision of Kaohsiung city is to encourage people to use the public transport more (Step 1). Under this urban vision, the goal is to raise the percentage of the public transport market share (Step2). Next, goal is to design the quantitative content of integrated transport policy alternatives to match the long-term urban planning of Kaohsiung City by expert interviews and discussions. Then, setting the GA parameters to generate the initial random population and start on this whole evaluation process. Figure 3 displays the convergence curves measured in terms of the summation of maximum transport market share. As can be seen from the figure, the market share can converge to 41.21% after the forty-ninth generation. The contents of this integrated transport policy invest MRT and LRT system; the parking fee for vehicle is 50 NTD per hour, and the motorcycle is 20 NTD per hour; the traveling cost of vehicle owner is 5 NTD and the Motorcycle is 2 NTD.
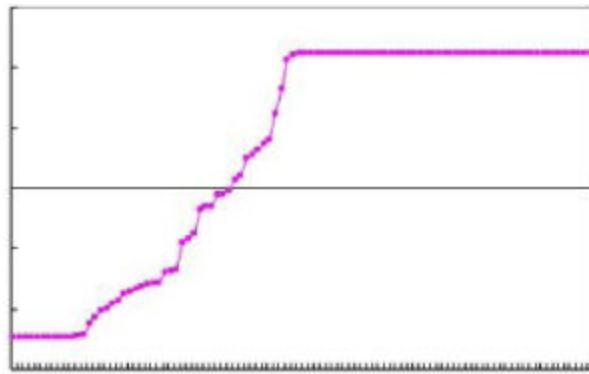
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Figure 3: Genetic Algorithm Results

## DISCUSSION AND CONCLUSIONS

When dealing with the urban transport problems effectively, long-term developments of the urban area should be fully considered in conjunction with land-use, socio-economy, environmental impact, finance and sustainability factors rather than being restricted in single phase of transport policy. Some results show that improving the urban transport problems depends on integrated transport policies that aim at reducing the demand of investment and impact huge costs. The efficiencies of assessment would be decreased by considering the multi-dimensional integrated transport policies because of complicated combination factors. The purpose of this project is to develop a new framework to facilitate the assessment of multi-dimensional integrated transport policies.

The combinations of factors including investment, pricing, management, and regulation were considered in the modified model. Genetic algorithms were employed to dissolve the interactions of considered factors in the proposed model. For this purpose, the genetic optimizer, combines the transport demand's four step analysis, (used to estimate travel demand in predicted year), with the transport policy integration, (used to combined different dimensions transport policy and strategies). Finally, the relationship between quantified objectives, policy combinations, and performances could be analyzed using the proposed model in this study. Decision makers can draw suggestions from the proposed model while drafting urban integrated transport policies.

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