AHP-BASED DECESION-MAKING PROCESS FOR CONSTRUCTION OF PUBLIC TRANSPORTION CITY MODEL: CASE STUDY OF JEJU, KOREA

Seunglim Kang [1] , Seongkwan Mark Lee [2]

ABSTRACT

Traffic congestion that results from the increased traffic demand due to the creation of new infrastructure (i.e., a newly built highway) has become a very serious problem in Korea that causes unnecessary social cost. To solve this problem, more effective transportation demand management should be considered simultaneously with the promotion of public transportation. New policies that promote transit ridership are appearing as a result of issues such as capacity and the environment.

The most suitable and effective public transportation policies are planned and executed within the context of a long-term strategy due to their large time and money costs. Therefore, a public transportation model should be developed after an adequate evaluation process in order to maximize social benefit and efficiency.

Methods for evaluating many alternative policies have already been introduced. The monetary evaluation methods (such as Cost-Benefit Analysis) have some limitations in reflecting various factors, especially considering qualitative variables that are related to decision-making problems.

On the contrary, the AHP (Analytic Hierarchy Process) is a flexible model that deals with the qualitative variables and allows us to make decisions by personal judgment in a logical way.

This paper provides a new decision-making process that is related to policies on the promotion of public transportation ridership. This paper also includes implementation of the process to the construction of a 'JEJU' public transportation city model to verify the applicability of the AHP method.

Since the new method includes a multi-criteria (particularly qualitative variables) analysis process and reflects expert opinions, it is therefore very useful for finding a more broadly acceptable solution for goal-oriented policy making. Planners and decision-makers can easily use this new method to prioritize transportation projects.

KEY WORDS

Public transportation city model, AHP (Analytic Hierarchy Process), Decision making process, Prioritization, Multi-criteria analysis

[1] Department of Urban and Regional Planning, University of Illinois at Urbana-Champaign, Urbana, IL., 61820, Phone 217-714-4564, kangsl@uiuc.edu

[2] Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, Urbana, IL., 61820, Phone 217-244-9210, smlee4@uiuc.edu

INTRODCUTION

Traffic congestion that results from the increased traffic demand due to the creation of new infrastructure (i.e., a newly built highway) has become a very serious problem in Korea that causes unnecessary social cost. To solve this problem, more effective transportation demand management should be considered simultaneously with the promotion of public transportation. New policies that promote transit ridership are appearing as a result of issues such as capacity and the environment.

The most suitable and effective public transportation policies are planned and executed within the context of a long-term strategy due to their large time and money costs. Therefore, a public transportation model should be developed after an adequate evaluation process in order to maximize social benefit and efficiency.

Methods for evaluating many alternative policies have already been introduced. The monetary evaluation methods (i.e., Economical Efficiency Analysis, Cost-benefit Analysis, etc.) that have been used to give priorities to the alternatives have some limitations in reflecting various factors, especially considering qualitative variables that are related to decision-making problems. From a certain point of view, the impacts are often difficult to be valued in monetary terms. These conditions make the implementation of monetary evaluation method such as Cost-Benefit Analysis (CBA) alone often inadequate in policy decision process.

On the contrary, the AHP (Analytic Hierarchy Process) is a flexible model that deals with the qualitative variables and allows us to make decisions by personal judgment in a logical way. Within the AHP, it is possible to reach an agreement by providing an effective framework for group decision making that imposes discipline on the group's thought processes. The AHP arranges a systematic framework for decision making by involving various decision factors. Assigning a numerical value to each variable of the problem helps maintain cohesive thought patterns leading to a conclusion. In addition, the consensual nature of group decision-making improves the consistency of the judgments and enhances the reliability of the AHP as a decision-making tool.

This paper provides a new decision-making process that is related to policies on the promotion of public transportation ridership. This paper also includes implementation of the process to the construction of a 'JEJU' public transportation city model to verify the applicability of the AHP method. We first reviewed similar examples of a public transportation city model, then selected eligible alternatives and provided the decision making process based on the AHP to make suitable policies through a reasonable evaluation process. Finally, we selected the most feasible alternative for the public transportation city model of JEJU applying the newly established policy-making process.

PUBLIC TRANSPORTATION CITY MODEL

Background and objective of public transportation city model

The increased use of passenger cars caused by decreased transit ridership has aggravated traffic congestion and environmental pollution, thus making transportation and environmental policies to solve those problems more necessary. Particularly, the transportation planning process has put increasing emphasis on the creation of a human-oriented and sustainable transportation system that is related to the urban and natural environment, human health, and the social and economic welfare of communities. A sustainable transportation system is one that allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, with equity within and between generations, is affordable, operates efficiently, offers choice of transport mode, supports a vibrant economy, limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, reuses and recycles components, and minimizes the use of land and the production of noise[3]. A sustainable transportation system also results in less transportation fossil fuel consumption and CO^2 emissions, less vehicle pollution emissions, less per capita motor vehicle mileage, higher transit ridership, less traffic crash injuries and deaths, and less transport land consumption. Public transit-oriented land use systems are needed for sustainability of urban transportation, reducing per capita vehicle travel and increasing the viability of walking, cycling and public transit. Particularly, focusing development around transit facilities has become a significant way to improve accessibility, support community and regional goals of enhancing the quality of life, and support the financial success of transit investment. The experiences of a new generation of transit systems highlight the powerful role that transit investments play in channeling urban development. Benefits attributable to transit-oriented development (TOD) initiatives include improved air quality, preservation of open space, pedestrian-friendly environments, increased ridership and revenue, reduction of urban sprawl, and reorientation of urban development patterns around both rail and bus transit facilities

The objective in constructing the public transportation city model is to solve present traffic problems, to enhance the city image, and to activate the city function by supplying a transportation system that reduces traffic demand and creates a human-oriented urban environment through the promotion of public transportation.

Case of public transportation policy

Lately, in most advanced countries, transportation policy has changed from transportation facility supply to traffic demand management and efficient transportation facilities operation. Transportation policies carried out mainly in one hundred and ten cities or so for the last twenty years were public transportation promotion (i.e., service improvement, preferential treatments), traffic system management (i.e. improvement of traffic signal system, effective management of road network), and parking management (i.e. control of supply and fare)[4].

Cities across many developed countries are investing in public transportation facilities and preferential treatments in view of the fact that the capacity for public transportation is much larger than that of the passenger car, and what is more, it has relatively less impact on environment. An effort to provide a bus-oriented public transportation system and to create pedestrian-oriented space is in progress to promote economic efficiency. Most cities have

---

3 The Centre for Sustainable Transportation, Definition and Vision of Sustainable Transportation, September 1997, URL: http://www.tc.gc.ca/programs/environment/sd/strategy0103/appendixC.htm, accessed on 25 February 2005.)

4 Urban travel and sustainable development, ECMT, OECD, 1995

made better bus services such as the improvement of vehicles and bus stops (i.e. bus information system) and increased bus supply (i.e. the operation of night buses). And applied methods were different according to the city size, that is, the number of population. In case of large-size cities of which population is over million (i.e. Seoul, Bogota, Sao Paulo, Curitiba), projects of a large scale (i.e., bus exclusive lanes, bus preferential signal system, light rail transit system, transfer center, etc.) that are very expensive have been carried out. On the other hand, in case of small and medium-size cities (i.e., Brussels, Brugge, Karlsruhe, Edinburgh, Dublin, Copenhagen), projects of a small scale (i.e., regular bus lane, fringe parking, etc.) have been progressed. And many small and medium-size cities have promoted the use of bicycles through installation of bicycle exclusive ways and bicycle preferential treatments, and have revitalized downtown throughout the installation of transit malls, and have enhanced the city image throughout the operation of new transit mode such as Tram.

POLICY-MAKING FOR PUBLIC TRANSPORTATION CITY MODEL

We established policy-making process based on AHP, and carried out a case study in Jeju city, Korea, where has tried to be constructed as a public transit city model.

Necessity of AHP application

Cost-Benefit Analysis (CBA) is normally conducted to verify the economic feasibility of possible alternatives. However, the inadequacy of CBA in dealing with intangible factors and strategic concerns is its main weakness (Shang et al. 2004), and may fail to capture all the impacts of using multiple decision-makers and multiple attributes. Moreover, many cost-benefit studies tend to underestimate the importance of the local society where the impact of project is felt most strongly (Azis, 1990), and CBA may not adequately identify the relationships between attributes and objectives.

But on the other hand, the AHP enables the decision maker to structure a complex problem in the form of a simple hierarchy and to evaluate a large number of quantitative and qualitative factors in a systematic manner under conflicting multiple criteria. The AHP apparently yields subjective preferences with greater precision, because the AHP method does not produce the numerical biases seen in the single-step method (Hagquist, R.F.,1994). And the approach does not require a definition of trade-offs between the possible values of each attribute (i.e., it is not necessary to build utility functions), and it allows users to understand how outcomes are reached and how weightings influence outcomes. Moreover, it is able to reach an agreement by providing an effective framework for group decision making which imposes a discipline on the group's thought processes, and by arranging within the systematic framework the decision making problem involving various decision elements. Assigning a numerical value to each variable of the problem helps decision makers to maintain cohesive thought patterns and to reach a conclusion. In addition, the consensual nature of group decision-making improves the consistency of the judgments and enhances the reliability of the AHP as a decision-making tool.

As stated above, the policies necessary to promote the public transportation depend on regional characteristics and traffic conditions of the objective area, and so for the more effective policy-making, it is desirable to collect the relevant expert opinions after thorough preliminary screening. For that reason, the reasonable group decision-making process that suits for general thought and intuition is needed. Therefore, this study selected the AHP which allows us to make decisions by personal judgment in a logical way.

Analytic Hierarchy Process

The analytic hierarchy process (AHP) is a multi-attribute modeling methodology to solve complex problems that involve multiple criteria, and provides a simple process for weighting portions of the hierarchy that can not be enumerated by directly. This method can formulate a general multi-attribute decision problem in terms of a decision tree where each of the hierarchy levels involves several types of criteria. The decision problem is how to compare the relative importance of the criteria in a systematic and quantitative manner.

Some of the concerns in applying AHP are making pair-wise comparisons between alternatives, the consistency of the comparisons, and the defensibility of the scores. The decision maker is required to judge the relative importance of each criterion and then specify a preference, which is rated on a scale from 1 to 9, for each decision alternative under each criterion. If there are *n* alternatives, then *n(n-1)/2* pair-wise comparisons are needed. Clearly, for expedient application of AHP, the alternatives must be limited to a reasonable number.

The result of AHP is a prioritized ranking that indicates the overall preference of each alternative. The decision maker should examine the scores to ensure that they are sensible and should be adequately aware of the issues so as to defend the scores. The consistency of the judgments of the decision maker can be measured with a consistency ratio (CR). The CR is calculated as follows:

$$CR = [(\lambda_{\max} - n)/(n-1)]/RI$$

Where, $\lambda_{\max}$ = the eigenvalue corresponding to the principal eigenvector

n = the number of alternatives or criteria being compared

RI = the random index, a dimensionless value that is a step function of n

The numerator of the above equation is termed the consistency index, and a CR of 0.1 or less is considered acceptable. If a decision-maker's responses fail the consistency test, then the analyst must repeat the process until consistent responses are obtained.

The application of AHP to the complex problem usually involves four major steps:

1. Break down the complex problem into a small number of constituent (decision) elements and then structure them in a hierarchical form.
2. Make a series of pairwise comparisons among the elements according to the given ratio scale.
3. Use the "eigenvalue" method to estimate the relative weights of the elements.
4. Aggregate these relative weights and synthesize them for the final measurement of given decision alternatives.

There are some applications of AHP in transportation evaluation. Saito (1987) used AHP to evaluate bridge improvement programs. Tracz and Wawrzynkiewicz (1993) used AHP in the selection of alternative public transport system. Hagquist, R.F., (1994) determined highway improvement needs by maximizing its "composite index", a performance measurement function that is a weighted sum of nine quantified highway condition factors for the sections of the road system. Khasnabis and Chaudry (1994) used the AHP in ranking transit privatization projects in the Detroit metropolitan, and they showed that AHP is a viable tool for rank ordering a large number of transportation projects following various weighting alternatives. Masami S. (1995) used AHP-based approach to identify the benefit structure of road network systems and to improve the development strategy in mountainous areas. Tabucanon and Lee (1995), in their study of evaluation of rural highway improvement projects in Korea, concluded that the application of AHP gave more balanced outcomes for various conflicting criteria compared to traditional economic evaluation method. Banai, R., (1998) assessed the suitability of land use around proposed light rail transit stations of a metropolitan area using the AHP. Tsamboulas, et al. (1999) identified five most suitable methods for transport evaluation and evaluated those five methods (i.e., REGIME, ELECTRE Family, AHP, MAUT, ADAM) based on their adequacy in handling complex and multidimensional evaluation of transportation projects. They suggested AHP is the method that satisfies almost all the listed criteria, and stated that the outcome of AHP method might be considered as a compromise solution. Guegan, D. P. et al. (2000) used the AHP as a multiple-criteria decision-making tool to prioritize traffic calming projects, and state the AHP must be completely aware of the issues surrounding the proposed traffic calming projects. Stephen, P. M., et al (2000) developed a new evaluation framework integrating the multiple-attribute value function (MAVF) technique with the AHP to evaluate a new traffic control system, and they proved this approach is successful by combining institutional and technical components into a flexible alternative. Zografos K. G. (2001) used AHP to identify the costs and benefits generated from introductino of ATT (Advanced Transport Telematics) Technologies in Haardous Material Fleet Management, and they performed comparative assessment of the alternatives by calculating the benefit-cost ratio which cannot be measured in monetary units. Kengpol, A. (2002) proposed a Design Support System (DSS) model based upon the AHP that can accommodate evaluation model and criteria in regarding to evaluate the investment in new distribution center. Khasnabis, S. (2002) developed a performance assessment tool based on the Analytic Hierarchy Process (AHP) and the Goal Achievement Technique (GAT) for Michigan transit agencies that receive operating assistance from the Michigan Department of Transportation (MDOT), and they stated that AHP as a better multi-criteria assessment tool because of its stronger mathematical foundation, its ability to gauge consistency of judgments, and its flexibility in the choice of ranges at the sub-criteria level. Kim, K. et al (2002) developed a decision model using AHP for a sample list of expansion projects under consideration by INDOT. They tested the system for its efficiency in project ranking processes, and a revised list of prioritization criteria is recommended based on findings from a series of sensitivity analyses. Gercek, Karpak and Kilncaslan (2004) employ AHP to evaluate three alternatives of rail transit networks in Istanbul and AHP was found to be useful for multifaceted planning process. Yin Y. (2004) employed the AHP as an adaptation evaluation tool to rank desirability of resource management plans. Chen, X., et al (2005) proposed an approach using multiple criteria fuzzy comprehensive evaluation combined with AHP to deal with a fare evaluation, and they stated that the proposed framework is a practical and efficient method for fare evaluation. Rahman, SM. (2005) developed a multi-criteria decision making approach to rank the potential sustainability indicators with the help of local and global expert opinions.

Preference for public transportation promotion policy

The study area, Jeju city with a population of about 0.3 million and an area of 255.5km^2 is a tourist city, where the bus has been used as the only public transportation because the population size is small and space is limited. But demand for the bus has been decreased continuously and instead taxies and rental cars have accommodated the demand, because of the poor bus service and particularly the lack of bus service for sightseeing. For that reason, the more use of residents and tourists can be ensured by providing the effective public transportation system. On the other hand, in case that the population is under million, it is recommended to provide bus-oriented public transportation in view of the fact that bus is a very efficient and flexible. Therefore, above all, the bus-oriented public transportation facilities and services should be improved and the good circumstances for the bus users and pedestrians should be provided.

We surveyed the preference for public transportation promotion policy through the questionnaire for five hundred bus users of Jeju city who will be the main beneficiary, and the result was considered in the alternative selecting process.

The result was that the request for diversification of bus routes (i.e., increase of purpose-oriented bus routes) (27.6%) was most evident, and the preference for the improvement of services and facilities (15.8%) and the installation of regular bus lanes (11.0%) were high. On the other hand, the preference for the improvement of tourist-oriented bus services (8.0%) was high in the view of the fact that Jeju is a tourist city.

Policy-making process based on AHP

The AHP was used to determine the priority of each of the alternative, that is, we selected optimum alternative necessary to construct the public transportation city model through successive priority setting based on the AHP as follows (See Figure1);

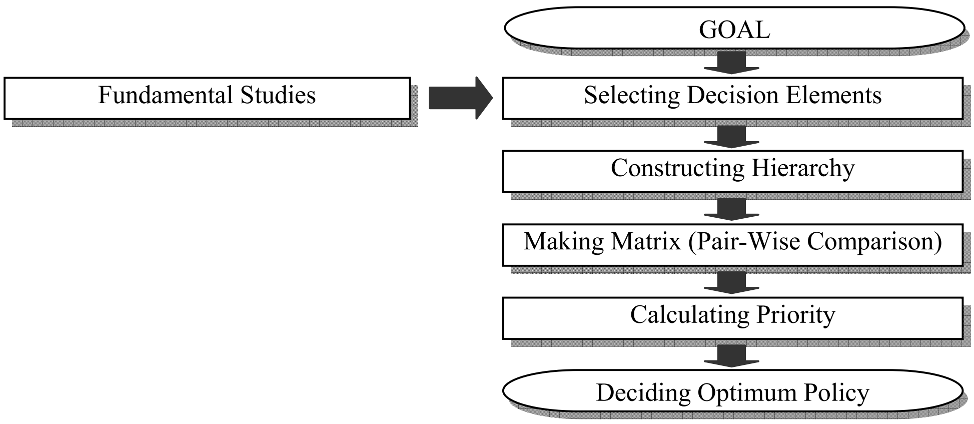

Figure1: AHP based policy-making process

Step 1: Selecting decision elements

Decision elements must be considered strategically and adaptively, responsive to local priorities and site-specific condition. Therefore we set the decision elements for Jeju as four kinds of objectives and related alternatives were selected considering the scale of the city, regional characteristics, and traffic conditions of the city (see Table 1). And in obtaining the elements, we have closely reflected expert's opinion (50 public transportation experts and 10 clerks from the department of transportation in Jeju city were engaged in the process) through the Delphi Technique to represent concrete experiences and consistency in priority.

Step 2: Constructing hierarchy

The decision making problems were structured systematically through the hierarchy (i.e., level 1: objectives, level 2: alternatives in Table 1).

Step 3: Making matrix

The core of the decision making process using multiple criteria analysis is the determination of a weight for each criterion. And within this process decision makers have to make compromise before taking final decision. In this study, site specific conditions, neighborhood's and expert's opinions were incorporated into the scoring of the pair-wise comparisons. We could obtain reasonable judgments through the group decision-making process in which a number of experts from the same field participated in order to assure objectivity of the priorities. Matrices that compare the relative importance of respective decision elements were constructed through pair-wise comparisons, which compare the hierarchical elements in pairs with respect to the relevant elements at the previous level[5], after reaching the common consent for the related expert opinions through the Delphi Technique.

Step 4: Calculating Priority

On the basis of the matrices which were derived from former step, the priorities[6] for decision elements by the level (i.e., level 1: objectives, level 2: alternatives in Table 1) were calculated, and the consistency of reply were verified by consistency ratio (CR).

Step 5: Synthesizing results

The set of overall priorities[7] that indicate the relative importance of evaluation factors were obtained by synthesizing the priorities of every level according to the top-down approach, and overall consistency of reply was verified by finding the composite consistency ratios.

Policy-making results

Table 1 shows the priorities for decision elements calculated according to levels and overall priorities of alternatives. In case of level 1 (i.e., priorities of four objectives for the public transportation city model), priority of the improvement of convenience and cleanness (0.34) was somewhat higher than others, and then came the improvement of accessibility and connection (0.25), the improvement of speediness and regularity (0.24), and the improvement of environmental protection (0.17) in order. In case of level 2, priorities of alternatives to

[5] The relative importance of elements was transformed into ratio scale.
[6] These priorities are significant in view of the fact that judgments are represented with meaningful numbers.
[7] It means composite priorities used priority of relevant criterion as weight of every factor.

attain respective objectives could be classified as four groups according to the objectives at level 1. First, for the improvement of speediness and regularity, priority of bus preferential treatments on streets (0.43) was the highest, and priority of bus preferential treatments at intersections (0.29) was similar to that of bus preferential treatments at the bus stops (0.28). Secondly, for the improvement of environmental protection, priority for installation of the transit mall (0.73) was the highest, then priorities for installation of the pedestrian road (0.15) and installation of the bicycle road (0.12) were almost similar. Thirdly, for the improvement of convenience and cleanness, priority for improvement of service and maintenance of facilities (0.38) was similar to that of the expansion of tourist oriented bus service (0.36). Lastly, for the improvement of accessibility and connection, priority for diversification of the bus route (0.56) was a little higher than that of installation of the transfer facilities (0.44). Simultaneously, the consistency of replies was verified because all the consistency ratios (CR) calculated by the level were less than 0.013, which was less than the predefined threshold, 0.1.

The overall priorities of alternatives for the public transportation city model were presented at the last column of the Table 1. Priority for diversification of the bus route (the expansion of the purpose-oriented bus route) (0.14), the improvement of services and the maintenance of facilities (0.13), installation of the transit mall (0.12), the expansion of tourist oriented services (0.12), installation of the transfer facilities (0.11), bus preferential treatments on streets (0.10) and the improvement of services for he disabled (0.09) were highly prioritized. Also, overall consistency of replies was verified at the same time. The composite consistency ratio (CR) was 0.017, which supported the consistency of the replies.

Finally we decided seven alternatives (Diversification of bus routes, Improvement of services and facilities, Improvement of services for the disabled, Installation of transit mall, Expansion of tourist oriented services, Bus preferential treatments on street, and Installation of transfer facilities) to improve convenience and cleanness, accessibility and connection, speediness and regularity, and environmental protection for the bus-oriented public transportation service.

Table 1: Priority by the level and Overall Priority

Level 1: Objective		**Level 2: Alternative**		**Overall priority**
Improvement of speediness and regularity (Improvement of operation condition through bus preferential treatments)	0.24	- **Bus preferential treatments on street** - Bus preferential treatments at intersection - Bus preferential treatments at bus stop	0.43 0.29 0.28	**0.10** **0.07** **0.07**
Improvement of environmental protection (Providing safe and comfortable environment for the pedestrian)	0.17	- **Installation of transit mall** - Installation of pedestrian road - Installation of bicycle road	0.73 0.15 0.12	**0.12** **0.03** **0.02**
Improvement of convenience and cleanness	0.34	- **Improvement of service and facilities** - **Improvement of services for the disabled** - **Expansion of tourist oriented services**	0.38 0.26 0.36	**0.13** **0.09** **0.12**
Improvement of accessibility and connection	0.25	- **Diversification of the bus route (Expansion of purpose-oriented bus route)** - **Installation of transfer facilities**	0.56 0.44	**0.14** **0.11**

Constructing the public transportation city model by these optimum alternatives will result in supplying transportation system, which will be expected to reduce traffic demand by increasing public transit ridership, and in the end, to create the efficient and human-oriented urban environment.

CONCLUSIONS

Recently, policies to promote public transit ridership are drawing attention from the perspectives of road capacity and the environment as an accepted and realistic solution to traffic problems that we face. Increased public transportation demand has historically resulted in decreased traffic demand.

This study examined various policies for the promotion of public transportation, presented a policy-making method based on the AHP, and applied the method to the city of Jeju, Korea. Consequently, a public transportation city model for Jeju found that it is desirable to promote bus-prioritized public transportation environment reflecting its characteristics as a tourist city.

The new method includes a multiple criteria (particularly qualitative variables) analysis process and reflects expert's opinions, and therefore is very useful for finding a more broadly acceptable solution to goal-oriented policy making problems. The new method introduced in this paper can be easily utilized by planners and decision-makers for prioritizing a list of transportation projects. However, future study should include some case studies to make the process practicable.

REFERENCES

Azis, I.J., (1990), "Analytic Hierarchy Process in benefit-cost framework: A post-evaluation of the Trans-Sumatra highway project", European Journal of Operational Research.

Banai, R., (1998), "Transit-Oriented Development Suitability Analysis by the Analytic Hierarchy Process and a Geographic Information System: A Prototype Procedure", Journal of Public Transportation, Vol. 2, No. 1

Chen, X., Lin, G., Yu, L., (2005), "Evaluation Analysis on an Integrated Fare Initiative in Beijing", Journal of Transportation Engineering, Vol. 120, No. 3, pp. 33-55.

Dueker, K.J., Pendleton, J.H., Rao, R., (1983), "Evaluation of Portland Transit Mall", Transportation Research Record 931, TRB.

Gercek, H., Karpak, B. and Kilncaslan, T., (2004), "A multiple criteria approach for the evaluation of the rail transit networks in Istanbul", Transportation Vol. 31, pp203-228.

Guegan, D. P., Martin, P. T., Cottrell, W. D., (2000), "Prioritizing Traffic-Calming Projects Using the Analytic Hierarchy Process", Journal of the Transportation Research Board 1708, pp 61-67.

Hagquist, R.F., (1994), "High-precision Prioritization Using Analytic Hierarchy Process Determining State HPMS Component Weighting Factors", Transportation Research Record 1429, pp 7-14

Kengpol, A., (2002), "The Design of a Support System (DSS) to Evaluation the Investment in New Distribution Centre Using The Analytic Hierarchy Process (AHP)", Capital

Investment Model and Transportation Model, http://www2.ipe.liu.se/rwg/igls/igls2002/Paper010.pdf.

Khasnabis, S. and Chaudry B. B., (1994), "Prioritising transit markets using Analytic Hierarchy Process", Journal of Transportation Engineering, 120(1), pp 74-93.

Khasnabis, S., Alsaidi, E., Liu, L., and Ellis, R.D., (2002), "Comparative Study of Two Techniques of Transit Performance Assessment: AHP and GAT", Journal of Transportation Engineering, Vol. 128, No. 6, pp. 499-508.

Kim, K., Bernardin, V., (2002), "Application of an Analytical Hierarchy Process at the Indiana Department of Transportation for Prioritizing Major Highway Capital Investments", Journal of the Transportation Research Board 1816, pp 266-278

Lawrence, W., (2002), "Trip Report: Rubber-Tired Trams BRT Project in the Paris Region", FTA.

Masami S., (1995), "Analytic Hierarchy Process (AHP)-Based Multi-Attribute Benefit Structure Analysis of Road Network Systems in Mountainous Rural Areas of Japan", International Journal of Forest Engineering Vol. 7, No 1.

Rahman, SM., (2005), "Sustainability Appraisal of Urban Transportation: Application of Analytical Hierarchy Process (AHP)", Conference proceedings, Environmentally Sustainable Development.

Saito, M., (1987), "Application of the Analytic Hierarchy method to setting priorities on bridge replacement projects", Transportation Research Record 1124 , pp 26-35.

Shang, J.S. Tjader, Y, and Ding, Y., (2004), "A Unified framework for multicriteria evaluation of transportation projects", IEEE transactions on Engineering Management.

Stephen, P. M., Michael, G. M., Jayakrishnan, R., (2000), "Decision Theory for the Performance Evaluation of a New Traffic Control System," Institute of Transportation Studies University of California, Irvine.

Thomas L. Satty, (1990), "Multicriteria Decision Making", RWS Publication.

Thomas L. Satty, (1995), "Decision Making for Leaders", RWS Publication.

Thomas L. Satty, Luis G. Vargas, (2001), "Models, Methods Concepts & Application of the Analytic Hierarchy Process", RWS Publication.

Tracz, M. and Wawrzynkiewicz, B., (1993), "Knowledge acquisition from multiple experts: a case of transport planning in Poland (chapter 14)", Expert System in Environmental Planning, Springer-Verlag, Berlin Heidelberg, pp 261-274.

Tabucanon, M. T. and Lee, H., (1995), "Multiple Criteria Evaluation of Transportation System improvement projects: the case of Korea", Journal of Advanced Transportation, 29(1), pp 127-134.

Tsamboulas, D., Yiotis, G. S. and Panou, K.D., (1999), "Use of multicriteria methods for assessment of transport projects", Journal of Transportation Engineering, Vol. 125, No. 5, pp. 407-414.

Yin Y., (2004), "Evaluation Tools to Identify Implications of Climate Change and Economic Development for Sustainability in Lijiang and Yulong Mountain Region, China", http://www.millenniumassessment.org/documents/bridging/papers/yin.yongyuan.pdf

Zografos K. g., (2001), "Assessing the Impacts from the Introduction of Advance Transport Telematics Technologies in Hazardous Materials Fleet Management", Journal of the Transportation Research Board 1709.