



AN ANALYTICAL RESEARCH BASED ON PLANNING AND EVALUATION OF ROAD NETWORK CONFIGURATION IN URBAN CONTEXT

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Abstract-

The way that an urban area develops, as well as the location of families, work hubs, and social and economic activities, are all impacted by the design of the urban road network. In order to create an equitable and sustainable urban growth model for cities, it is vital to take supply disparity in the urban road network into account. This paper aims to apply the fractal analysis concept to evaluate the urban road network and seeks an evaluation index of the layout and internal structure characteristics to guide the optimization and adjustment of the urban road network. This is important because it guides urban land use, effectively uses geospatial space, and promotes sustainable urban development. Determining evaluation criteria for residential area road networks is the aim of this project. In order to do this, a study of previous research on urban plan paradigms, neighborhood road network designs, and road network assessment criteria is conducted. These results in the selection of 42 road network evaluation criteria using first and second expert questionnaire surveys. Regional and interregional road networks made up the two categories of the road network evaluation criteria. The former were separated into public transport and motorways (major roads and auxiliary main roads), while the latter were separated into motorways (distributed roads, local roads), pedestrian ways and bicycle ways in order to determine the assessment criteria.

Keywords— *Road Networks, Evaluation Criteria, Eco-Friendly Transportation Network, Residential Area.*

INTRODUCTION

Road networks in residential areas are important facilities enabling residents to have mobility and enjoy comfortable lives, and are one of the most important social infrastructures that form cities. However, residents living in residential areas adjacent to roads are actually harmed both directly and indirectly by these roads, although the actual level of such harm is not yet clear. Since road networks in existing residential areas are planned based on the subjective ideas of planners, there are many difficulties in road network planning from the perspective of the residents. This has led to diverse problems such as poorly- designed road network plans for residential areas, in terms of the efficiency, safety and comfort of roads. Recently, user-oriented paradigms have been appeared in road network plans, such as pedestrian-oriented or public transportation oriented road network designs, as well as designs that consider eco-friendliness. Walking and bicycling are now viewed as valid modes of transport. TEA-21 states: "Bicycle transportation facilities and pedestrian walk- ways shall be considered, where appropriate, in conjunction with all new construction and reconstruction of transportation projects, except where bicycle and pedestrian use are not permitted" (Federal Highway Administration, 2003). Road network plans that consider the changes in the paradigm of urban plans are important for the creation of comfortable cities. While there have been studies related to urban road network evaluation that have considered the mobility and efficiency of motor ways, pedestrian ways and bicycle ways, there have been no studies that perform an integrated evaluation of these three factors. Therefore, in this study, evaluation framework reflecting the perceptions of the users of road networks in residential areas, indexes for the evaluation of motor ways, eco-friendly transportation networks such as pedestrian ways and bicycle ways, and public transportation networks were developed. In developing the evaluation criteria, both the quantitative evaluation criteria considered in previous studies such as mobility and efficiency, and qualitative evaluation



criteria such as safety, comfort and convenience, were considered. The major contents of this study can be broadly divided into four parts. First, evaluation criteria were derived through studies related to urban planning paradigms, neighborhood road network designs and road network evaluation criteria. Second, questionnaire surveys of experts were conducted to develop road network evaluation criteria, and the weighted values of these evaluation criteria were calculated. Third, measures to examine and score road network evaluation criteria were presented. Fourth, the effectiveness of the road network evaluation criteria was reviewed through case studies.

LITERATURE REVIEW

(i) Road Network Plan Factors in Urban Plans Paradigms- Road network plan factors presented in diverse urban plan paradigms were reviewed, and the major evaluation criteria to consider when planning residential area road networks were derived. The Compact City Theory is an urban planning theory centered on the relationships between transportation and city densities, and presents public transportation linkage, traffic safety, energy efficiency, air pollution and noise as major plan factors (Michael, 1994; Peter and Harry, 1997; Haiyan et al., 2008). Smart Growth is a combined plan that uses lands in existing cities for public transportation facilities, pedestrians, residence and commerce, and this is a trend in urban development that aims to preserve a good environment and a high level of comfort. It presents that, to this end, improvements in walking, accessibility to public transportation, and the formation of pedestrian-friendly neighborhoods are important (Steven et al., 2006). New Urbanism is an ideology that aims at a return to cities centered on the neighborhood, with a humanistic focus, and it presents the formation of efficient and environment friendly pedestrian ways and the securing of connectivity between motor ways and walking spaces as major plan factors in road network plans (Larry, 1999). TOD (Transit-Oriented-Development) aims to solve urban problems arising from passenger car oriented land use plans, and to this end, it presented the shortening of passenger car moving distances, the construction of pedestrian-friendly street linkage networks, railroad plans and the reduction of air pollution as major plan factors (Ronnie, 2006; Robert and Jennifer, 2008).

(ii) Changes in Neighborhood Road Network Design Paradigms

(a) Traditional Neighborhood Development (TND)- A Traditional Neighborhood Development (TND) is a human scale, walk able community with moderate to high residential densities and a mixed-use core. Compared with conventional suburban development, TNDs have a higher potential to increase modal splits by encouraging and accommodating alternate transportation modes. TNDs also have a higher potential for capturing internal trips, thus reducing vehicle miles traveled. TNDs have a high proportion of interconnected streets, sidewalks and paths. Streets and right of ways are shared between vehicles, bicycles and pedestrians. The dense network of TND streets functions in an interdependent manner, providing continuous routes that enhance non-vehicular travel (David et al., 2000). The development encourages walking and biking, enhances transit service opportunities, improves traffic safety by promoting low speed, and cautions driving while fully accommodating the needs of pedestrians and bicyclists.

(b) Neo-Traditional Neighborhood Development (NTND)- Neo-Traditional development is a generic term for a set of more specific proposals that go by a variety of names: urban village, compact cities, and compact urban development (Susan, 1992). Neo-TND (NTND) has begun to take root in the United States, and its implications for traffic engineering are significant. Because of the market preference for automobile travel during the past several decades, suburban communities have been designed primarily for the private automobile with very little attention paid to other modes of travel. The traffic engineering profession has evolved within this market framework and has developed a highly sophisticated and dependable set of residential and urban street guidelines for safe and efficient motorized traffic (Eva et al., 1992). The scale and close mixing of land-use types characteristics of NTND plans necessitate that the typical suburban transportation mode balance (automobiles, transit, pedestrian, and bicycles) be reworked to focus on an intentional effort to



reduce the design speed of automobile traffic in order to allow pedestrians and non- motorized modes equal or preferred right-of-way.

(iii) Studies Related to Road Network Evaluation Criteria- Residential area road network plans are very important for the creation of comfortable urban environments, and user demand for road networks that offer more convenient movement is increasing day by day. For this reason, diverse studies have been conducted to determine appropriate evaluation criteria for the motorways, pedestrian ways and bicycle ways that are included in residential areas. Jin (1998) derived evaluation criteria for roads intended for combined use by pedestrians/cars from the viewpoints of cars, pedestrians and residents, for application to the formulation of

district traffic plans. To review the evaluation criteria by stake- holder, running speeds, crossroad forms, accident rates, designed speeds and road landscapes were presented for drivers, while pedestrian traffic volumes, lighting facilities, pedestrian crossing facility intervals and accident rates were the major criteria for pedestrians, and car traffic, distances to public transportation facilities, road noises, air pollution and vibrations were important evaluation factors for residents. James et al. (2003) divided a 10-mile section of road located in Chapel Hill, North Carolina into 31 segments to evaluate the pedestrian and bicycle ways adjacent to roads. When evaluating the pedestrian ways, sidewalk presence, light, sidewalk material, AADT, speed, buffer width, number of thru lanes, sidewalk condition and sidewalk width were considered in calculating a final walking suitability score. When evaluating the bicycle ways, speed, bike lane, frequent curves, severe grades, lack of sidewalks, pavement condition, parallel parking, bike lane width and land use were considered in calculating the final bicycle suitability scores. Sheila (2003) suggested that when evaluating pedestrian ways, the satisfaction felt by pedestrians can be practically evaluated by considering the following criteria of adequate walkways: continuous sidewalks, comfort, comfortable walking surfaces, maintainability, and environmental conditions. Scott et al. (2004) suggested that in addition to using operation states to evaluate city expressways, evaluations that can reflect the quality of services perceived by drivers should be considered. To this end, they surveyed city expressway users on the importance of travel time/speed, density/maneuverability, safety, civility, information on traffic conditions, weather, and road conditions, and based on the results, travel time/speed, density/maneuverability, safety, and information of traffic conditions were deter- mined to be of the highest importance. Michael (2005) presented six criteria for evaluating the convenience of pedestrian way plans when urban plans are made, including connectivity, linkage with other modes, fine-grained land use patterns, safety, quality of path and path context. Lindsey et al. (2008) suggested that an enhanced quality of life for residents is very closely related to livable streets, and presented traffic injuries, noise and air pollution, vehicle speeds and traffic speeds as items to be considered when designing these livable streets. In presenting design guidelines to secure convenience of movement for cyclists and pedestrians, FHWA (2008) suggested that safety, convenience and comfort should be secured in access systems between all starting points and all destinations in a community. In a design manual for bicycle ways in large U.S. cities, Campo (2009) defined the major criteria to be considered in planning bicycle way networks as accessibility, directness, continuity, route attractiveness and low conflict. In addition, he suggested that traffic volume, average motor vehicle operating speeds, traffic mix, on-street parking, sight distance and the number of intersections and entrances should also be considered in the area of traffic operation, and that shared lanes, wide outside lanes, bike lanes, shoulders and separate bike paths should also be considered in the area of geometrical structures. Todd et al. (2009) presented guidelines that can be utilized when planning pedestrian, bicycle ways and criteria for evaluation methods. They mentioned accessibility, crosswalks, grade, street furniture, tree route, and surfaces as guidelines for pedestrian way plans, and suggested bicycle parking, lighting, maintenance, pavement structure, user conflict and vegetation as guidelines for bicycle way plans.



CALCULATING WEIGHTED VALUE AND DEDUCTING ROAD NETWORK EVALUATION CRITERIA

(i) Deriving Road Network Evaluation Criteria- Residential area road network evaluation criteria were derived through a five-step process.

STEP 1: Selecting preliminary evaluation criteria through an analysis of previous studies

STEP 2: Designing questionnaires using preliminary evaluation criteria

STEP 3: Deriving evaluation criteria through the first expert questionnaire survey
(One Sample t- test)

STEP 4: Designing questionnaires for calculating the weighted values of evaluation criteria

STEP 5: Calculating the weighted values of evaluation criteria through the second expert questionnaire survey (AHP analysis) From the evaluation criteria established in previous studies, 63 preliminary evaluation criteria that coincided with the purpose of the present study and that were considered to enable the measurement and quantification of road network evaluation criteria were selected. These 63 evaluation criteria were largely divided into two groups: criteria for interregional road networks, and criteria for regional road networks. The former primarily considered the efficiency of interregional movements of the residents of residential areas, and these networks were divided into motor- ways (main road, auxiliary main road) and public transportation. The latter considered the comfort, safety and convenience of the movements of residents in residential areas, and these were divided into motorways (distributed, local roads), pedestrian ways, and bicycle ways. The first questionnaire survey for analyzing the suitability of the evaluation criteria was conducted on a total of 100 experts, with 50 experts in urban plans and 50 experts in traffic plans, and one sample t-test was conducted using the collected data. In the analysis, since the grades of each of the evaluation criteria with a suitability score of 3 indicated “slightly suitable” and “very suitable” in the one sample t-test in this study, “average,” which was a score of 3, was set to the critical value. The hypotheses were tested by testing alternative hypotheses ($H_1: > 3$) based on null hypotheses ($H_0: \leq 3$) and decisions were made based on the significance level (p-value) of the results of one sample t-test within a confidence level of 95%.

(ii) Calculation of the Weighted Values of Evaluation Criteria- Analytical Hierarchy Process (AHP) was used to calculate the weighted values of the residential area road network evaluation criteria. AHP is a method used to express quantitative factors as values that can be used in complex decision-making situations that have multiple criteria. This is characterized by paired comparisons of the importance of many evaluation criteria for consistent determination of the priorities (Saaty, 1980). To calculate the weighted values of the evaluation criteria, AHP questionnaires for the second expert questionnaire survey were prepared using the 42 evaluation criteria, and a survey was conducted on 40 experts: 20 urban planners and 20 traffic planners. Through consistency tests ($CI > 0.6$) 36 questionnaires were finally selected to conduct AHP. Excel was used when calculating the weighted values of the evaluation indicator. The AHP results indicated that the regional road networks were more important than the interregional road networks. Within interregional road networks, motorways were more important than public transportation, and within regional road networks, pedestrian ways and bicycle ways, as eco-friendly means of transportation, were more important than motorways.

TECHNIQUE FOR RATING ASSESSMENT CRITERIA

(i) Overview of the Method of Scoring the Evaluation Criteria- To score the road network evaluation criteria, the 42 evaluation criteria were divided into quantitative and qualitative indicators. Data for qualitative indicators were collected through field surveys and simulations. Among the efficiency indicators, V/C and average traffic speeds were obtained using the results of EMME/2 simulations, while among planning quality indicators, the degree to which the design criteria was satisfied was obtained through actual field measurement surveys based on road installation criteria. Among the accessibility indicators, distances to subways and bus stops were suggested to be scored



using the surveyed values measured using maps. In addition, the number of conflicts among safety indicators, the density of street trees among comfort indicators, and the intervals between pedestrian crossing facilities were applied with the values obtained through field surveys. For these quantitative indicators, the scoring method consisted of dividing the ranges corresponding to \pm based on mean values (μ) into high ($\mu+\sigma$, 5 points), medium (μ , 3 points), and low ($\mu-\sigma$, 1 point), considering the normal distribution characteristics of site surveyed values. Unlike quantitative indicators, qualitative indicators are items that cannot be easily expressed as continuous values, and data for these indicators were collected through questionnaire surveys conducted on the residents of residential areas. The qualitative indicators were the evaluation criteria corresponding to the comfort and convenience of motorways, pedestrian ways and bicycle ways, and these were evaluated through questionnaires consisting of 5-point Likert scale questions.

(ii) Method Used to Score Residential Area Road Network Evaluation Criteria- The seven characteristics constituting residential area road network evaluation criteria were divided into efficiency, environmental quality, planning quality, accessibility, convenience and comfort, and the methods used to score each characteristic. The 42 evaluation criteria for evaluating residential regions' road networks have been drawn through the test of the suitability of evaluation criteria conducted earlier.

(iii) Planning Quality- The planning quality indicators are evaluation criteria related to the design criteria and forms of motorways, pedestrian ways and bicycle ways that comprise harmony with land use plans, showing the relationships between land use and roads, conformity to design criteria, which is an evaluation item for the geometrical structures of roads, and the suitability of road hierarchies meaning the connectivity of roads. Harmony with land use plans is a qualitative indicator, for which no clear criteria have yet been presented. Therefore, in this study, the harmony of the roads with the use of the surrounding lands was scored through field surveys by applying 5-point Likert scales. The conformity to design criteria was evaluated through field measuring surveys that were conducted based on the design criteria provided under "Regulations regarding the structures facilities of roads" (MLTM, 2009), while the suitability of road hierarchies was evaluated based on whether the road hierarchies of main roads auxiliary main roads distributed roads local roads were appropriately arranged.

(iv) Accessibility- The accessibility indicator is intended to evaluate the accessibility to subway stations and bus stops for residents, and consists of distances to subway stations and bus stops. To measure the evaluation criteria for this indicator, the locations of subway stations and bus stops in the vicinity of residential areas were marked on a map, and the distances from the center of the region to the subway stations and to the bus stops were measured to score the accessibility. To give the evaluation scores, the distances were divided by 100 m intervals from a reference distance of 500 m that generally means the radius of station regions.

USING CASE STUDIES TO VERIFY THE EVALUATION CRITERIA

(i) Selection of Case Regions- As case regions for verifying the residential area road network evaluation criteria, the "Dongdaemun Jeonnong · Dapshim-ri rearrangement promotion regions" included in the downtown redevelopment projects that are actively being implemented in Korea were chosen as subject regions appropriate for evaluating the practicality of the road network evaluation criteria derived in this study. The case region comprised a project area of 903,967 m², and a population of 34,834 in 13,561 households. Its geological state and future development plan diagram are presented in Fig. 1.

(ii) Evaluation results of the case region- Using the scoring methods established for the 42 road network evaluation criteria, the road networks in the case region were evaluated. Before and after implementation of the development project, the road networks were evaluated through field surveys in the case region and user questionnaire surveys (RP surveys), and by measurements using the plan drawing of the development project and user questionnaire surveys (SP surveys), respectively. Due

to the large area of the case region, it was divided into 5 zones for conducting the surveys to evaluate its road networks. The quantitative and qualitative evaluation criteria were applied with the average values of the resultant values of the five zones and of questionnaire surveys on 20 residents, respectively.



Figure 1- The Present State of the Case Region and Development Plan Diagram (Before-After)

The results of the evaluation of the road networks in the “Dongdaemun Jeonnong · Dapshim-ri rearrangement promotion regions” using the residential area road network evaluation criteria are presented. To compare the scores before and after the implementation of the residential area development project, the road network evaluation score of the subject region was increased by 26.65 points from 44.25 points before to 70.89 points after the implementation of the rearrangement promotion region development project. While the evaluation scores for interregional road networks were not significantly changed, those for regional road networks were. Although most of the evaluation criteria had higher scores after implementation of the residential area development project, the scores for the V/ C ratio and average traffic speeds indicators were reduced. This was attributed to the increased car traffic volume arising from the development project, and the natural increase of the traffic volumes in the areas surrounding the project site. In addition, the amount of exhaust gas emission is an evaluation criterion that is closely related with traffic volumes and speeds in areas surrounding the project site, and this showed lower scores after the project implementation. On the other hand, motorways (distributed, local roads), pedestrian ways and bicycle ways that fell under the category of regional road networks showed higher scores after the project implementation. This indicated that the road network conditions in the residential areas were improved by the residential area development project, and road network plans for users were established. In addition, the practicality of residential area road network evaluation can be enhanced by considering the qualitative evaluation criteria, the residential area road network evaluation should be conducted considering evaluation criteria that reflect the viewpoint of users, such as safety, comfort and convenience, and that the LOS evaluation criteria currently provided in the “road capacity handbook” should be improved.

CONCLUSION

The purpose of the paper was to provide evaluation standards for road networks in residential areas. The selection of 42 road network evaluation criteria through first and second expert questionnaire surveys, the computation of weighted values, and the establishment of procedures for scoring the resulting evaluation criteria were the results of the review of studies pertaining to urban plan paradigms, neighbourhood road network designs, and road network evaluation criteria. Interregional and regional road networks were the two categories into which the road network evaluation criteria



were separated. The former were separated into public transport and motorways (major roads and auxiliary main roads), while the latter were separated into motorways (distributed roads, local roads), pedestrian ways and bicycle ways in order to determine the assessment criteria. Eco-friendly transport networks, such bicycle and pedestrian lanes, are more significant than other networks, according to an AHP analysis of the weighted values of the assessment criteria, which also showed that regional road networks are more significant than interregional road networks. Each assessment criterion's unique qualities were taken into consideration while presenting the techniques for scoring the road network evaluation criteria, which were split into quantitative and qualitative indications. Lastly, a case study that looked at a residential area rehabilitation project of the "Dongdaemun Jeonnong• dapshim-ri rearrangement promotion regions" explored the applicability of these assessment criteria.

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