Analysis of Evaluation Indicators for Service Performance of Roads/Bridges

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***Abstract*—In Korea, the number of bridges increases by 4.2% every year. The percentage of bridges that have been built 20 years ago is approximately 20% of all bridges. For safe and efficient management of bridges, whose number is on the rise, an objective evaluation of facilities to be managed is required. This study was intended to develop an evaluation model in terms of service performance. For this purpose, service performance factors were determined from previous literatures and consultations with experts from various fields. Importance of each evaluation indicator was calculated by reflecting opinions of experts from various fields through questionnaires.**

***Index Terms*—infrastructure, evaluation, service performance, AHP analysis**

I. Introduction

In Korea, 26,920 bridges have been built as of the end of 2009. These have been increasing at 4.2% every year. The number of bridges that have been built 20 years ago is 5,342 and it is approximately 20% of all bridges [1]. For the safe and efficient management of bridges whose number is on the rise, an objective evaluation of facilities to be managed is required [2]. However, most evaluation processes mainly focused on structural deficiencies and other important aspects of infrastructure were often neglected regardless of their importance, such as, performance, public demand, capacity, etc., [3].

In this connection, this study was conducted to find factors that could influence the service performance and also develop evaluation indicators for service performance. Service performance was defined by the service level index that represented user's satisfaction, convenience or inconvenience and the performance level index that represented the facility's capacity and maintenance/ management. Service performance factors and important evaluation indicators that satisfied previous literatures and Korea's current conditions were determined through consultations with experts. As all factors could not have the same importance, relative importance between evaluation indicators was calculated using the AHP analysis method by collecting opinions of experts from various fields. Results gathered from this study will be used as basic data for the calculation of evaluation rating that may show the facility's current conditions.

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II. Review of Literature

An evaluation report on America's infrastructure facilities was published in 1988 by NCPWI (National Council on Public Works Improvement). The physical condition of each facility was evaluated and divided into eight categories (highways, mass transit, aviation, water resources, water supply, wastewater, solid waste and hazardous waste). Another infrastructure facility evaluation report was published by ASCE (America Society of Civil Engineers). Evaluation was done on 16 facilities (ports, railways, airports, roads, dams, water supply, wastewater, hazardous waste, solid waste, waterways, levees, public parks, bridges, energy, schools and mass transit). Evaluation indicators established were capacity, operation and maintenance, public safety, funding, future need, resilience, innovation, structural defect, performance defect, and conditions [4].

On the other hand, Canada's infrastructure evaluation report was published for the first time in 2012 by the Canadian Infrastructure Report Card Project Steering Committee. For the evaluation report, conditions of infrastructure facilities of 123 municipal governments from a total 346 municipal governments were evaluated through voluntary questionnaire by local organizations. For facilities related to four categories (drinking water, wastewater systems, storm water management and roads), current conditions and maintenance states were evaluated. Evaluation criteria established were health, safety, security, environmental and economic impacts, reliability, quality of and access to service, capacity to meet demand, asset preservation, renewal, decommissioning, and adaptability [5].

Moreover, Australia's infrastructure evaluation report was published by the Institution of Engineers Australia, a group of expert engineers. As a non-profit organization formed by engineers from various fields, this institution works hard to take prior measures against economic, social, and environmental risks caused by climate change. The infrastructure facility evaluation report published in 2010 includes evaluation results for 11 categories (roads, rail, airports, ports, water, wastewater, potable water, irrigation, electricity, gas, and telecommunication). Evaluation indicators established were road safety, environmental sustainability, road quality, data

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availability and status, strategic policy, integrated framework, institutional framework, strategic plan result, funding for expansion, operation outcome, and maintenance/repair and funding [6].

Lastly, Japan's infrastructure facility evaluation report was published in May 2008 by the special committee of JSCE (Japan Society of Civil Engineers). Evaluation indicators for each facility were established. Facilities evaluated were divided into five categories (roads, rivers, water supply/wastewater, seashore, and harbors). Evaluation criteria for road facilities were established as securing of mobility, pleasantness and convenience of road, reduction in damage from earthquake and fire, safety and security of traffic, pleasant road environment, creation of good view, road repair, improvement of environment related to atmosphere and noise [7].

III. Selection of Evaluation Indicators

Canada's evaluation indicators for roads and bridges in terms of service performance of infrastructure facilities were used as basis of this study. Selected as evaluation indicators were security, public health, mobility, environmental quality, social equality and economic consideration. Evaluation was implemented by selecting the following detailed evaluation indicators:

1) *Security*: Expected traffic/ real traffic, reliability/failure ratio), road sufficiency rating survey, bridge condition index, health index, traffic safety characteristics (posted information, interval, risk factor), deck rideability evaluation, remaining service life, decrease in the number of fatalities and wounded, the number of vehicular accidents, protection against effects of environmental change, protection against intentional property damage, the number of bridge collisions by trucks and vessels

2) *Public health*: Real dBA vs. permitted level, reduction in the emission of greenhouse gas (GHG), nitrogen oxide (NOx), sulfur oxide (Sox) and volatile organic compounds (VOC), protection against vibration/excessive deformation, exposure to harmful substances, intentional property damage

3) *Mobility:* Ratio of actual traffic capacity/design traffic capacity, average speed/regulation speed, the number of specific bridges/the number of restricted bridges, relative delay ratio, population ratio in the vicinity of highways, vehicle (transportation method) operation cost, average snow removal time, road sufficiency rating survey, bridge condition index, health index, ramp lining up, horizontal interval, vertical interval, detour length, protection against the effect of environmental change and protection against intentional property damage

4) *Environmental quality*: Reduction in the emission of vehicle gas, greenhouse gas (GHG), nitrogen oxide (NOx), sulfur oxide (Sox) and volatile organic compounds (VOC), energy use and vehicle noise

5) *Social equality*: Population ratio within 1km of roads (accessibility in road unit), vehicle (transportation method) operation cost, traffic congestion and accident cost

6) *Economic consideration*: Ratio of profit/cost (cost-benefit ratio), ratio of life cycle cost/profit, total cost/person, average cost per trip or tonnes-km, the number of restricted bridges, detour length, transfer of project, productivity, effect of expansion, facility value, road sufficiency rating survey, health index and bridge condition index

7) Based on evaluation indicators used in previous studies, this study obtained the following new evaluation indicators through consultation with experts to meet current conditions in Korea. As evaluation needs to be implemented according to objective evaluation criteria and methods, by focusing on key evaluation indicators rather than including many evaluation indicators, the detailed evaluation indicators were selected as follows:

TABLE I. The Detailed Evaluation Indicators

Performance Category	Feature	Classification of Detailed Indicators
Serviceability	Maneuverability	Paving condition
		Bridge lighting
		Vibration serviceability
Performance	Maintenance and management	Existence/non-existence of inspection facility
	Demand and capacity	Traffic demand

Evaluation factors in this study were divided largely into two categories; serviceability factor and performance factor. Serviceability was defined as user's convenience, and performance was defined as capability that a facility can provide. In case of a bridge, maneuverability that made a driver feel comfortable was determined to be important. Therefore, road paving condition, bridge lighting, and vibration serviceability were selected as detailed evaluation indicators. As maintenance and management was determined to be important in terms of performance, existence/non-existence and conditions of an inspection facility and traffic demand that reflected capacity were selected as detailed evaluation indicators.

1) *Road paving condition*: Evaluation considered vibrations that a driver felt while driving due to uneven road surface or condition and damaged road surface.

2) *Bridge lighting*: Evaluation considered whether or not road light standards were met according to the type of road and traffic specified in the guidelines of road safety facility installation and management.

3) *Vibration serviceability*: Evaluation as to what degree people felt the vibration of a road / bridge.

4) *Existence/Non-existence of Inspection Facility:* Evaluation for existence/non-existence and conditions of road inspections required to maintain and manage a road / bridge.

5) *Traffic capacity*: Evaluation as to whether or not traffic was adequate for a driver to use facilities

conveniently or traffic was too heavy to cause inconvenience.

IV. ANALYSIS OF THE EVALUTION INDICATORS

Through a questionnaire sent through e-mails, a survey was conducted to reflect the opinions of various experts. These included sending the questionnaires to links to relevant homepages in the web. The survey questions included review of adequacy and importance of each evaluation indicator of a road / bridge.

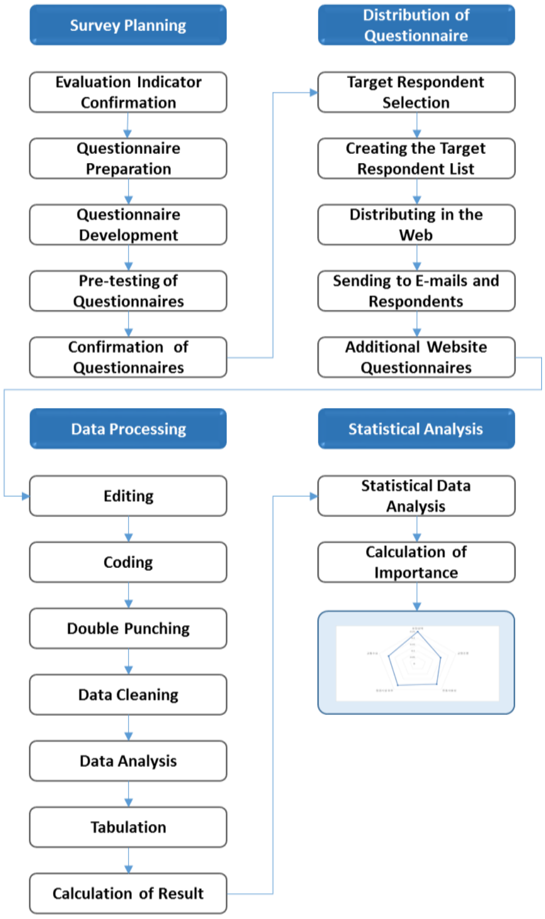

Figure 1. Survey procedure

A. Survey Method and Procedure

Through questionnaires, the survey procedures were: survey planning, distribution of questionnaires in the web, data processing, statistical analysis, and importance analysis (Fig. 1).

B. Survey Respondents

There were a total number of 30 respondents. The distribution of age groups was the following: the percentage of respondents in their 40s was 52% and the percentage of respondents in their 30s was 32%, which were higher than other age groups. The distribution of respondents according to the number of years of work experience was the following: the percentage of respondents with over 15 years and less than 20 years of work experience was 28%. The percentage of respondents with over 20 years of work experience was 55%. As the percentage of respondents with longer years of work experience was higher, the credibility of the questionnaire could be considered as high. The type of respondents' affiliated organizations was the following: the percentages of respondents affiliated with private companies, public research institutes and schools were 41%, 33% and 15%, respectively (Fig. 2). The distribution of industry, academy and research institute could be considered to be fairly adequate.

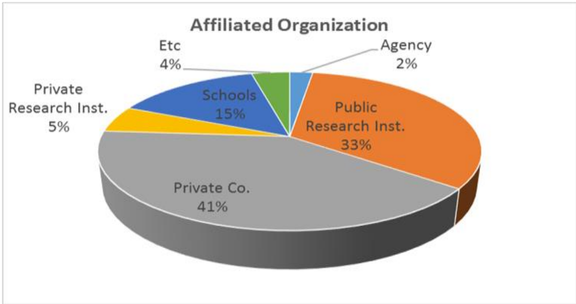

Figure 2. Adequacy analysis

C. Adequacy Analysis

Whether or not each evaluation indicator was adequate was evaluated using a 5-point scale, the result showed that paving condition was the most adequate and all evaluation indicators were above 3 points or adequate (Fig. 3).

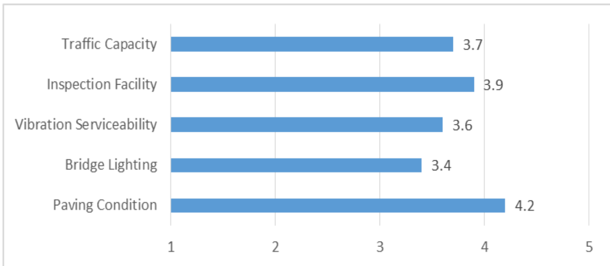

Figure 3. Adequacy analysis

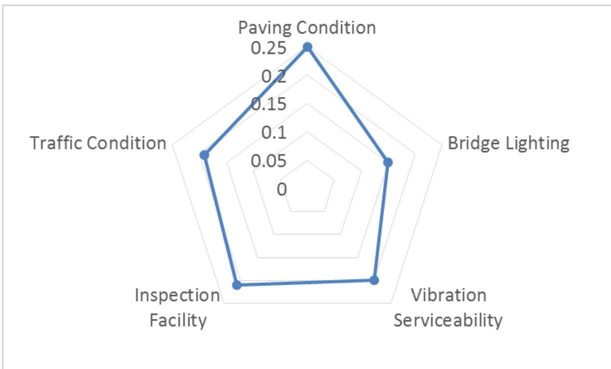

Figure 4. Importance analysis

D. Importance Analysis

The consistency index was analyzed to verify how logical and consistent the respondents made their evaluation before analyzing the importance. The consistency index value was found to be 0.0005. A lower consistency index value represented a higher logical consistency. If the value was below 0.1, responses could be considered as logically consistent. Therefore, results of this study could be considered as reasonable.

Results of importance analysis were as follows: Importance for paving condition was found to be 0.25 which was the highest. Next to paving condition, the order of higher to lower importance value were existence/non-existence of inspection facility, vibration serviceability, traffic demand and bridge lighting. The importance value for bridge lighting was the lowest at 0.15 (Fig. 4).

E. Other Comments

- Increase maintenance, repair and inspection in terms of safety
- Reflect paving condition and deterioration of paving
- Provide a safety facility in case of accident
- Provide disaster prevention facility, such as hydrant, fire extinguisher and escape direction guide in the evaluation indicators
- Specify quantitative evaluation criteria to check conditions
- Include non-daily indicators, as well as, daily indicators
- Consider visibility, turbidity and brightness in terms of maneuverability
- Provide separate guidelines for distinguishing natural drainage versus forced drainage
- Evaluate lining deformation in terms of performance
- Evaluate crack in terms of performance

V. Conclusion

This study was intended to provide objective indicators in the safe and effective facility management evaluation of roads / bridges whose number is on the rise. Evaluation indicators were selected by focusing on service performance, especially from real user's standpoint. Moreover, the importance of each evaluation indicator was calculated. A survey through questionnaires was conducted for the confirmation of evaluation indicators. The following steps were done: development of questionnaire, distribution of questionnaire in the web, data processing, statistical analysis, and calculation of importance.

Adequacy analysis results showed that all evaluation indicators were found to be adequate. Importance analysis results showed that the order of higher to lower importance value was: paving condition, existence/non-existence of inspection facility, traffic capacity, vibration serviceability and bridge lighting. Other comments by respondents included: necessity to reflect increase of maintenance/repair/inspection; provision of deterioration of paving, guide facility, visibility and crack on evaluation indicators.

Therefore, we plan to reflect additional evaluation indicators that can be considered to be important and develop a more objective and systematic facility evaluation system in future studies. We hope that our study results can be used as basic data for the calculation of evaluation rating to show the facility's current conditions.

Acknowledgment

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