A COMPREHENSIVE APPROACH FOR EVALUATING AND PRIORITIZING SMALL SCALE ROAD INVESTMENT PROJECTS

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Abstract: Recently many small-scale road investments, such as community road and pedestrian crossing, have been made in Seoul. Some of these projects, however, can not be justified by only executing economic feasibility analysis. The main purpose of this study is both to suggest a technique that enables multi-criteria evaluation for a set of small scale transportation projects and to make a package called HINES (Highway INvestment Evaluation System) in order to implement the proposed technique. HINES is a decision support system that includes transportation planning model and related database for each project. It allows what-if type analysis so that different set of priorities can be generated with different set of weight schemes of analysts. The total sixteen projects were evaluated and prioritized using the HINES.

1. INTRODUCTION

The distinction between evaluation and choice is not always clear. In fact, the interaction of the choice and evaluation phases can be so complicated that is difficult to differentiable between these activities (Manheim, 1979).

The evaluation process is difficult due to the existence of nonquantifiable impacts and the complex nature of the more tangible impacts. The need for the development of more systematic approaches to transport policy, program assessment, and project evaluation has been recognized for a long time. In addition to intuitive and consensus ranking, several techniques have evolved from economic theory and mathematical programming methods.

In this paper, several methods for prioritizing small scale road projects will be introduced and compared with the one that we developed. The method that we developed is basically comprehensive evaluation method in a sense that it can handle both quantitative and qualitative factors simultaneously and various interest groups that will affect and be affected with the implementation of projects. The proposed method was further implemented in the form of a decision support system (DSS) equipped with database, model base, and user interface. It was developed for the purpose of streamlining the routine process of small scale project evaluation that are currently undertaken manually by the city of Seoul Metropolitan Government (SMG).

This paper consists of four parts. In section 2, a brief overview of ranking methods for evaluation will be introduced along with the current evaluation process currently employed by the SMG. In section 3, as a methodological expansion, the comprehensive evaluation method was introduced with an emphasis on how we gathered scores for various evaluation criteria hat will be used for calculating the overall score. Finally, the schematic structure of the proposed system will be browsed and the system be tested with actual data. At the end of the test run, the conclusion and future research agenda are also presented.

2. QUICK OVERVIEW OF EVALUATION METHODS

2.1 Evaluation in Decision Making Process

Evaluation facilitates decision-making by appraising the positive impacts and negative impacts of alternative options in terms of either a single or multiple decision criteria (Papacostas and Prevedouros, 1993). During evaluation process, planners normally adopt either efficiency or effectiveness, or both, as a yardstick to select the best one among some available alternatives. Normally, the ranking or priority itself is graded based on order that each alternative is associated with its efficiency or effectiveness. Here, brief overview of both methods are presented.

2.1.1 Efficiency based Method

Efficiency is defined as the ratio of the quantity produced (output) to the resources required for its production (input). Especially, when both the numerator and the denominator are converted to the same measure of economic value, their ratio is referred to as the economic efficiency (Papacostas and Prevedouros, 1993).

Therefore, in order for an alternative to be economically feasible, the economic efficiency should be greater than unity. With the time dimension included, three major economic feasibility indices have been most frequently used for economic evaluation and prioritizing. They are:

NPV the present worth of an alternative's benefits minus the present worth of its costs. Hence a positive NPV implies economic feasibility.

B/C the ratio of an alternative's discounted benefits to its discounted costs. A B/C greater than unity implies economic feasibility.

IRR interest rate that just equates the discounted benefits and costs, that is, the rate at which the NPV equals zero and the B/C ratio equals unity. This rate is then compared with a predetermined minimum attractive rate of return reflecting managerial policy and profit expectations to assess the project is attractive or not (Papacostas and Prevedouros, 1993).

2.1.2 Effectiveness Analysis

Not all impacts associated with proposed alternatives are often possible to be expressed in monetary terms. Effectiveness came out to consider this kind of situation. Effectiveness is defined as the degree to which an action accomplishes its stated objectives. It differs from efficiency in that it need not have to explicitly express all impacts in the same scale of measurement (Papacostas and Prevedouros, 1993).

2.2 Issues Related to Efficiency based Methods

Although the foregoing efficiency based methods look objective since they are based on quantitative perspective, it is not so always as it may seem at first glance. Its major limitation may be classed into problems of impact enumeration, valuation, and distribution. The selection of an appropriate interest rate and the treatment of price inflation and deflation are also problematic.

Here, the issue of impact enumeration means that not all impacts, except major economic impacts, have been considered in the analysis although no evaluation technique can possibly include all of the impacts. Impact distribution refers to the fact that the benefits and costs are distributed unevenly between individuals and groups. For example, some persons may have to relocate their residences or businesses to permit the construction of a highway that could result in travel time and fuel saving for another group, the users of the new highway.

3. THE CURRENT EVALUATION PROCESS OF ROAD PROJECTS BY SEOUL METROPOLITAN GOVERNMENT

3.1 The Practice of Current Evaluation

Projects that will be implemented by SMG can be classified into two categories. One is that needs an inspection (in a sense it may be considered as evaluation and choice) whereas the other does not. The former involves the followings:

- projects whose cost exceeds around 4 millions[1]
- projects that will be implemented with foreign loan
- projects that mayor specially designate.

Projects that doesn't need the inspection involves ones that already determined from upper level decision making process (for example, projects that the central government decided to implement) or works that need an urgent progress.

[1] Currently, SMG contains 25 Ku's under the main city office, headquarters, which are the fundamental bodies of self government and administration. Here, the cost itself may be either from the main office or from the Ku's request to main office.

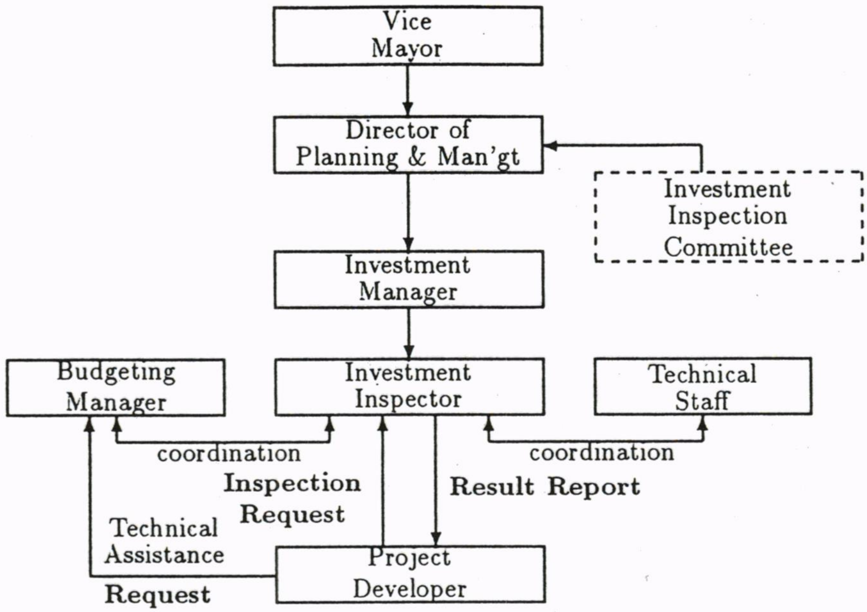


Figure 1: Schematic Diagram of Current Inspection Process by SMG

The brief inspection process is broken down as two phases. The first phase starts every March and ends in May. During this period, the inspector is supposed to be the main office or the branch office that is responsible for the project implementation. We call this as first screening. The evaluation and ranking method employed are basically effectiveness based analysis and pure ranking method based on overall scores that reflect the associated effectiveness of projects. Details of this method is described next section.

The second phase of the inspection falls between June and July for about two months. During this stage, the inspector is the director of planning and management who supports both mayor and vice mayor directly. We call this phase as second screening. The method employed in this phase is similar to that of the first screening phase. The director, however, can form a investment inspection committee, if there needs be. The basic flow containing both phases are depicted in Figure 1.

3.2 The Current Scoring Method

This method examines four aspects (criteria): congestion releasing, economic, social, and policy-oriented effects. Again, each criterion contains three subitems (impacts) with its related scores and each subitem is scaled from zero to a hundred percentage. The overall score out of these criteria amounts to 100. The Table 3.2 summarizes the overall impacts and criteria that are currently used for evaluation.

For example, if a project is the one that has the following characteristics, the overall score that the project would have will be calculated as follows:

In this case, the overall score will be: $(0.75\times9+1.0\times12+0.75\times9)+(0.75\times8+$

criterion		impact		scale				score
area	%	area	%	100%	75%	50%	25%	
Flow Effect	30	congestion relief	40	at-grade intersection	bottleneck relief	connectivity increase	etc.	12
		expansion scale	30	$> 35m$	$> 30m$	$> 25m$	$1 - 25m$	9
		distribution traffic	30	ring road	arterial	local road	etc.	9
Economic Effect	25	employment effect	30	$> 2,000$	$> 1,000$	> 500	< 500	8
		compensation percentage	40	less than 20%	more than 20%	more than 50%	more than 70%	10
		work period	30	less than 1 year	less than 2 years	less than 3 years	more than 3 years	7
Social Effect	20	facility shutdown	30	none	etc.	public facility	semi-public facility	6
		years pass after notice	30	more than 10 years	more than 7 years	more than 3 years	less than 3 years	6
		distance from CBD	40	more than 15 km	more than 10 km	more than 5 km	less than 5 km	8
Political Effect	20	focal work type	50	city level	district level	citizen level	etc.	6
		benefit aspects	40	subway connection	entrance opening	connection improve	etc.	6
		internal priority	10	first group	second group	third group	fourth group	3

Table 1: Current Criteria, Impacts, and Scores Adopted by SMG

$0.75\times10+0.75\times7)+(1.0\times6+0.5\times6+0.5\times8)+(0.5\times12+1.0\times10+0.75\times3) = 75.5.$

- 30m long over-bridge at-grade intersection facility connecting a major arterial,
- the compensation cost among the total cost, 1.5 million, is about 30 percent and the construction will be completed within two year,
- there will be no closure of civilian facilities due to this project and it is 5 years since the notice of urban planning activities. At the same time, the facility will be located around 7 km from the urban center (CBD).
- It is a long desired project by inhabitants that also connects subway near there. However, the authorities concerned in the city office still consider this project as the second group that doesn't have to come first as city's urgent projects.

The structure of this method is a simplified version of the comprehensive matrix method that will be introduced later. Conceptually the combination of

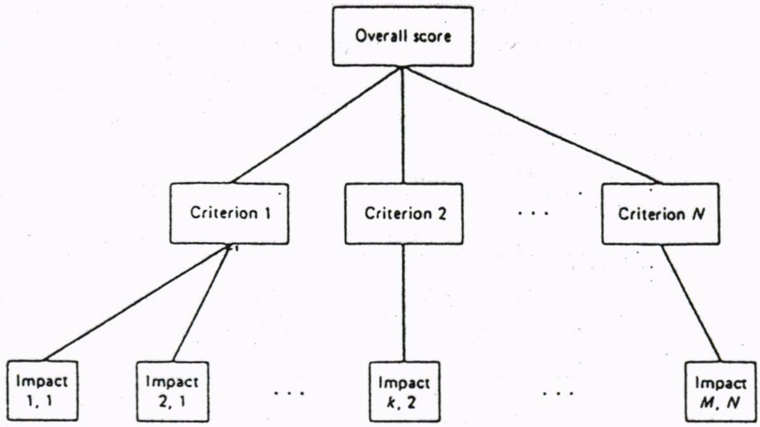


Figure 2: Impacts, criteria, and overall score

a set of impacts into a criterion is identical to the derivation of the overall score from a set of quantified criteria. The evaluation of very complex systems may require more than the three levels of aggregation as illustrated in Figure 2.

Of course, the ranking will be determined based on its overall score. The current method, however, leaves something to be desired in a sense that (1) it doesn't have a proper mechanism that takes the quantitative aspect into account, and (2) the qualitative items are too broadly categorized and the weights or scores associated with these items and subitems are quite subjective.

4. THE PROPOSED EVALUATION METHOD

4.1 Basic Concept

As has been pointed out in Section 2.2, the method that SMG currently employs for the evaluation of road projects has some limitations. That is, its major limitations are impact enumeration, valuation, and distribution. To overcome the issue of impact enumeration, criteria and impacts have been devised through the prudent analysis of the past three year inspection file and interview with transportation experts. The derived evaluation criteria are listed in Table 4.2.

The issue of impact distribution has been partially resolved by the introduction of five different interest groups. They are (1) operator group who operates the facility, (2) user group who will be benefited from the implementation of the project, (3) budgeting staff who will actually allocate the resources, (4) inspector group who will evaluate and choose the projects for implementation, and (5) technical body group who focuses on the difficulty and/or easiness of project implementation. The five groups listed above have been proved to be statistically significant within 5 % level of significance. That is, for all impacts except one-size of disbeneficiary, each group showed different importance or weights. The details of the MANOVA analysis has been omitted here.

(a) impact tableau

impact	efficiency	pollution
project A	3	2
project B	2	4

(b) value information file

value	city	resident
efficiency	4	2
pollution	1	3

(c) scores (project by group

score	city	resident
project A	(3x4)+(2x1)=14	(3x2)+(2x3)=12
project B	(2x4)+(4x1)=12	(2x2)+(4x3)=16

(d) group weight on facility type

weight	city	resident
arterial (A)	0.7	0.3
community Rd.(B)	0.4	0.6

(e) final score and ranking

ranking	calculation	score	ranking
project A	(0.7x14)+(0.3x12)	13.4	2
project B	(0.4x12)+(0.6x16)	14.4	1

Figure 3: Concept of the Comprehensive Matrix Method

Therefore, the proposed comprehensive matrix evaluation method requires two sets of information–information about actions (impact tableau) and information about values based on different interest groups (value information file) as shown in Figure 3. If there are two projects like (a), and ther value information are shown as such in (b), the overall scores of A, B projects can be calculated via matrix calculation (c). Finally, if two groups have values for project type as shown in (d), the final score over all impacts and groups are calculated as shown in (e). The details of this method is described in Chapter 9 of Manheim (1979).

4.2 Weight Determination: Value Information Files

Even after the problem of impact distribution has been solved, there would still remain the practical problem of determining the weights in value information file. In practice, the method like using multidimensional utility functions for each individual for establishing weights over various impacts is very time consuming and of limited value (Manheim, 1979).

Such being the case, we determined to do a field survey for establishing the weight scheme, just thinking that people can express their values best (1) when they are confronted with real alternatives and their associated impacts that they can perceive and understand, (2) when they understand the range of feasible options that are available, and (3) when they are stimulated to clarify their own values through the process of learning about the alternatives and their consequences.

Survey was done with the impacts listed in Table 4.2 during October of 1993. It was basically done through meeting interviews for 172 people that are made up of public servants both city headquarters and branch offices, researchers of Seoul Development Institute, and some civilians working for their organizations.

criteria	impacts
total cost	• construction cost • land compensation cost out of total cost • $\frac{compensationcost}{totalcost}$ • commercial area compensation cost • impediment facility compensation cost • $\frac{maintenancecost}{constructioncost}$
size of beneficiary	• number of inhabitants • size of commercial area • population size of economic activities
size of disbeneficiary	**no civil petition case** • number of inhabitants • size of commercial area • population size of economic activities **with petitions from transportation area** same as those in no civil petition case **with petitions from urban planning area** same as those in no civil petition case **with other petitions** same as those in no civil petition case
pollution level	• NO, NO_2 • particles
general characteristics	• surrounding conditions. • problems with local government • construction starting and ending time
economic efficiency	• benefic-cost ration (B/C)

Table 2: Newly Devised Impact Tableau Containing Criteria and Impacts

For each item, the weight (from each interest group) was scaled from -100 to 100 in the questionnaire. Since each item has a different unit and meaning, the surveyed weights should be normalized (first phase) and shifted to all positive values (second phase) so that all weights may be applied to produce the overall scores. The followings shows the formulas that were used for two phases.

$$Z_i^p = \frac{r_i^p - m_i}{\sigma_i}$$

where,

Z_i^p = normalized score of individual p's weight on impact i

r_i^p = score of individual p's weight on impact i

σ_i = standard deviation of impact i's weight

Z values from this transformation still have to be transformed once again to be successfully applied for the proposed method. That is, it should have all positive values. Otherwise, the overall score of a certain project may have a distorted meaning since the plus and minus values together may offset the overall effect. Therefore, the following transformation was used for making all transformed values into positive values[2].

$$Z'^p_i = Z_i^p + |min(Z_i^p), \forall\ p|,\ \forall\ i.$$

After this transformation, the final weight obtained is the arithmetic mean of the total n individuals interviewed expressed by:

$$W_i = \frac{\sum_p^n Z'^p_i}{n}$$

Table 3 shows the final calculated value information file.

4.3 Subarea Analysis and Economic Evaluation

One technical feature employed in this study is subarea analysis. Since we are only dealing with small scale projects ranging from (1) district to district level arterial, (2) community roads, (3) at-grade intersection facility, to (4) pedestrian crossing facility, the conventional method of assigning all O/D trips onto the whole network is quite inefficient and time-consuming. That is, the net effects out of the project implementation is supposed to be attenuated.

In order to overcome this problem, the concept of "windowing" or "focusing" in UTPS has been exploited. The essence of this concept is to generate a new subarea network automatically without touching the actual network file that contains from-node, to-node, capacity, and speed, etc. To achieve this, we used Urban Analysis Group's TRANPLAN package. Specifically, **hnis** submodule for handling network data has been used (For more, see TRANPLAN User's Guide,

[2]The exceptions for this transformation are for the items for which the negative values of Z score have meaning. That is, items like petitions-related and pollution level don't have to be transformed.

Item	Detailed item		Weights				
			User	Operator	Technical Staff	Budgeting Staff	Inspector
Size of beneficiary	Population		0.7971	0.6333	0.9623	0.7124	0.8933
	Population size of economic activities		0.7244	0.8558	0.7114	0.5430	1.2188
	Increasing scale of land values		0.3429	0.0115	-0.0019	0.1871	0.6089
Economic efficiency			- 0.5403	0.8024	0.5765	0.7794	0.8202
Size of beneficiary	Civil petition	Population	0.5616	0.3691	0.6636	0.7295	0.3460
		Population size of economic activities	0.5704	0.3012	0.6409	0.4441	0.4207
		Size of commecial area	0.2907	0.1231	0.3672	0.3747	0.3162
	Proposed petition	Population	0.5210	0.5210	0.5073	0.5688	0.2181
		Population size of economic activities	0.5204	0.6347	0.5480	0.4590	0.3532
		Size of commecial area	0.5034	0.2974	0.1709	0.0722	0.1624
	Urban planning petition	Population	-1.5270	-1.8517	-1.8730	-1.9093	-1.2435
		Population size of economic activities	-1.5548	-1.5345	-1.5350	-1.6098	-1.3867
		Size of commecial area	-1.6551	-1.2370	-1.4372	-1.4366	1.1939
	Other petition	Population	0.0484	0.2549	0.1554	0.3895	0.1392
		Population size of economic activities	0.1611	0.4275	0.2421	0.2848	0.0296
		Size of commecial area	-0.0795	0.1698	0.0349	0.1665	0.1224

Table 3: A Sample of the Value Information File Transformed

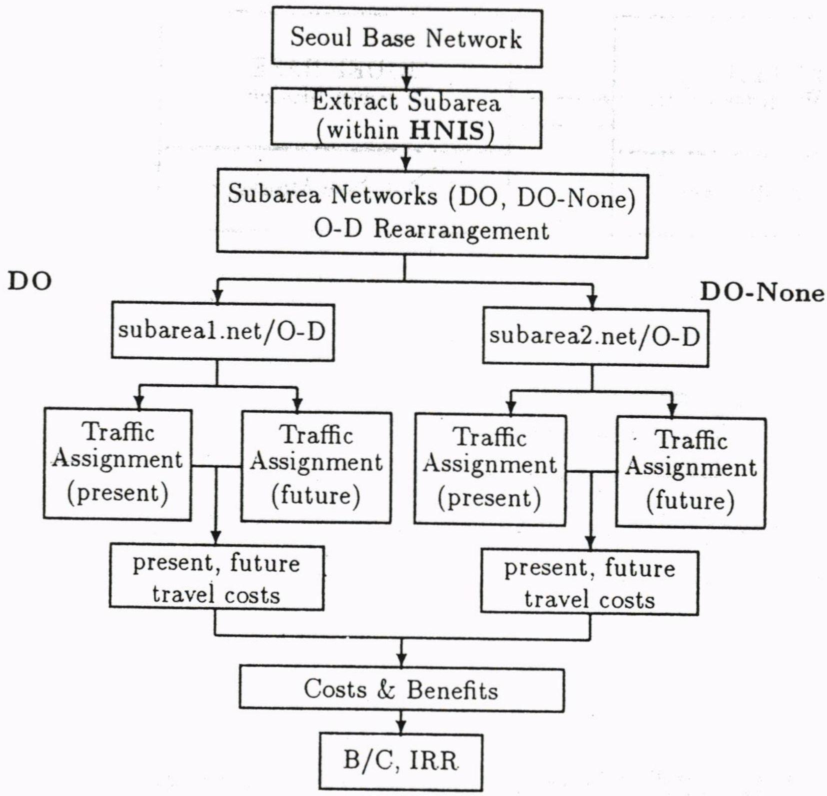


Figure 4: Process of the Subarea Network Analysis

Urban Analysis Group, 1993). During the hnis session, three files are normally created. The first file is extracted subarea which no project will be done. The second file is network file that includes projects to be implemented (evaluated). Finally, a supplementary file called **tpsubex.in** is produced to help rearrange the current O/D into extracted O/D system[3].

The other aspect related to subarea analysis is O/D extraction based on the above newly set up zone system. For example, if the extracted subarea has twelve zones–three internal zones and external zones (actually the links that cross the current (extracting) cordon lines) are nine, the 520 by 520 trip tables are automatically shrunk to 12 by 12 matrices. This is currently done inside the proposed decision support system and the process is shown in Figure 4.

Economic evaluation part in the system consists of two phases. One is transportation cost calculation via traffic assignment and the other is to convert this cost into monetary unit in order to find B/C ratio with discounting process for 20 years after the completion of a project. (The unit of transportation cost is veh$\times$time, i.e., $\sum_i v_i t_i$, where v_i is the volume of traffic on link i and t_i is average time cost on link i.)

Only this transportation cost was considered as benefit item, and construction and maintenance costs as cost item. Here, the value of travel time and the discount rate were assumed to be around 4,000 won per hour and 13 percent,

[3] Currently, around 520 zones and 8000 links are contained in the network

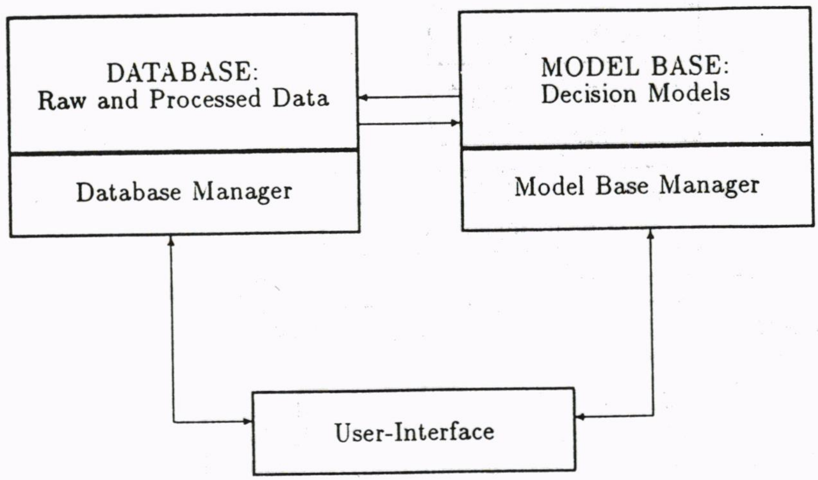


Figure 5: Basic Components of Decision Support Systems (DSS)

(Han and Kim, 1989)

respectively.

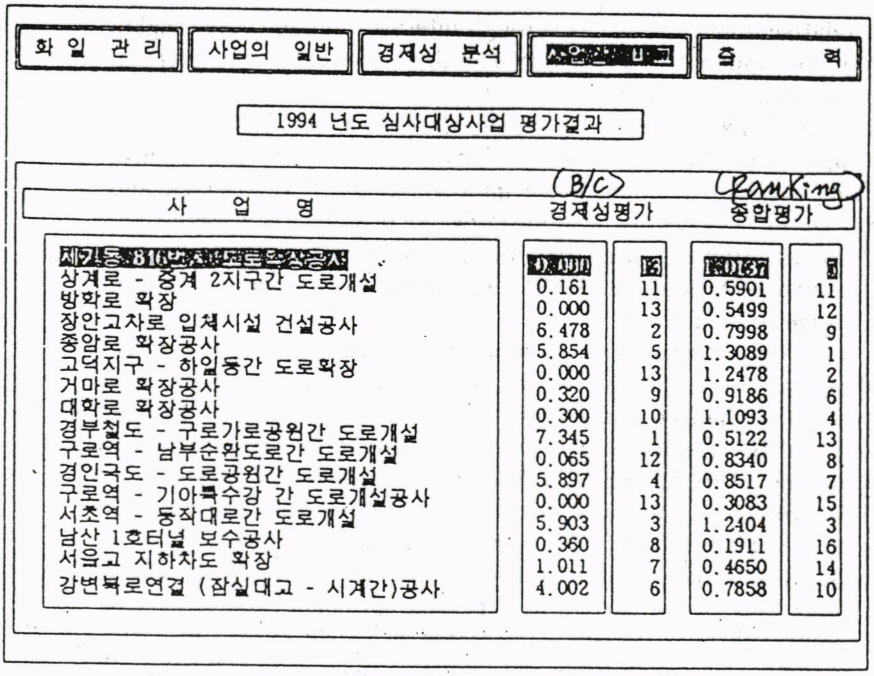
5. IMPLEMENTATION OF A DECISION SUPPORT SYSTEM

As Kroeber and Watson (1987) point out that several recent trends, including advances in computer hardware and software, particularly in personal computers, enable public servants (from lower ranked officials to executives) to use computers readily for their decision making, the proposed concept of evaluation has been wanted to be implemented in the computer.

The DSS is a distinctive type of urban information system because it has unique structures (Figure 5) and deals with a unique type of problem. One could say that DSS is an enhanced version of DBMS, upgraded by the addition of a model base. In fact, the output of DBMS serves as an input of DSS. In this study, the DSS paradigm has been selected since the problems we are facing is that they are quite semi-structured and include both quantitative and qualitative aspects.

The model base has diverse models such as transportation models, economics models, and etc. In the design of model base, the design of impact tableau and value information file, the method of score calculation of each item have been developed, whereas most of transportation models were borrowed from TRANPLAN-package including assignment, network extraction, and O/D rearrangement.

The database contains every project's data and characteristics year by year. Currently, there doesn't exist a specific database manager as we can see in



사 업 명	경제성평가 (B/C)		종합평가 (Ranking)	
세기동 816번지 도로포장공사	0.000	13	1.0137	5
상계로 - 중계 2지구간 도로개설	0.161	11	0.5901	11
방학로 확장	0.000	13	0.5499	12
장안고차로 입체시설 건설공사	6.478	2	0.7998	9
종암로 확장공사	5.854	5	1.3089	1
고덕지구 - 하일동간 도로확장	0.000	13	1.2478	2
거마로 확장공사	0.320	9	0.9186	6
대학로 확장공사	0.300	10	1.1093	4
경부철도 - 구로가로공원간 도로개설	7.345	1	0.5122	13
구로역 - 남부순환도로간 도로개설	0.065	12	0.8340	8
경인국도 - 도로공원간 도로개설	5.897	4	0.8517	7
구로역 - 기아특수강 간 도로개설공사	0.000	13	0.3083	15
서초역 - 동작대로간 도로개설	5.903	3	1.2404	3
남산 1호터널 보수공사	0.360	8	0.1911	16
서울고 지하차도 확장	1.011	7	0.4650	14
강변북로연결 (잠실대교 - 시계간)공사	4.002	6	0.7858	10

Figure 6: Example of Output

common commercial database management system such as dBase series. Users, however, can directly change the values of items whenever values needs to be changed.

One important feature of a DSS is a user interface, which facilitates interaction between the user and the system. We developed a full-down menu system as a graphical user interface. The Figure 6 shows an example of pull-down menu along with the final results over 16 projects as mutually exclusive alternatives.

The original system, named HINES (Highway INvestment and Evaluation System) was built with 486 type PC compatible computer with 500 Mb hard disk, VGA card, and mouse. The RAM size was not a critical factor since both the language (Turbo C) and the package (TRANPLAN) were working well with only conventional memory. However, more than four megabyte of RAM, VGA or SVGA graphic card, and a mouse are recommended for porper use of the system.

6. CONCLUSION

In this study, comprehensive matrix method for evaluating road (small-scale) investment projects has been proposed and the concept has been implemented as DSS in a PC. The method is able to handle both quantitative and qualitative impacts generated by the implementation of projects since each item has been measured with relative important scores through interview survey. The weights out of the survey are supposed to be used by default. However, the weights can be modified interactively by each user.

We evaluated the HINES system in a subjective manner. Three criteria we used were applicability, user-friendliness, and structuredness. Twenty five users representing the aforementioned five interest groups were selected and tested with the system. The results in terms of degree of satisfaction were 82%, 68%, and 72% for applicability, user-friendliness, and structuredness, respectively (Seoul Development Institute, 1993). This means the structure of user interface leaves some to be desired.

As for the improvement plan, several issues have been pointed out. First, the issue of subjectivity in weight determination still considered to be improved since the weights can be changed in a temporal sense. Therefore, the mechanism like AHP (Analytical Hierarchical Process) may be adopted to serve as weight determination module inside HINES DSS. Second, the problem of database integrity should be overcome. Currently, the costs in the database and network and O/D data are roughly estimated. To improve this status, the use GIS seems to be appropriate in spite of its huge initial costs in constructing both spatial and attribute data. Finally, the current system only considers each project as single and mutually exclusive. However, the scores of closely related projects, which also means very close in geographical distance, may overwhelm that of any single project to be evaluated even though the evaluation score of individual projects are just lower than others' and negligible. The similar phenomenon also appears in the traditional knapsack problem in operations research. Features like this should be incorporated in the future in order for the available resources to be effectively allocated.

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