APPLICATION OF MULTI-ATTRIBUTE DECISION ANALYSIS TO KOREAN TRANSPORTATION SYSTEMS

Dong Sung Cho

<CONTENTS>

I. BRIEF SUMMARY OF THE PAPER

The review of the governmental decision making processes and the academic studies on the transportation policy shows that the scholars fail to provide the decision makers with a reliable and systematic frame of reference for tackling complicated problems in the field. The weaknesses and the possibilities for improvement of the currently available analytic techniques are discussed.

Author: Planner of Gulf Oil Corporation

Next, I suggest a more comprehensive technique called Multi-Attribute Decision Analysis and show how it can be implemented for a specific problem. Because of my familiarity with Korea, and my interest in studying and helping this country, I chose to carry out the analysis using a case which was evaluated by the Department of Transportation of Korea a few years ago. The technique, however, may be applied to any problems which involve various conflicting issues. The major advantage of Multi-Attribute Decision Analysis is that the decision maker can see the whole dimensions of the problem by identifying his objectives and systematically evaluate the alternatives against those objectives.

II. THE PRESENT STATE OF THE ART

The scientific and systematic approach to the decision making by the government is hard to find. Evaluating between investment in rail versus investment in road, the government officials use transportation costs including initial investment and operating cost as the sole criterion (For example, see Chapter III of this paper). Where there is an existing railway, the decision makers may be in favor of the existing system just because the investment and the experiences are already available. However, other criteria in addition to cost are often relevant and should be considered. For example, in choosing between a railroad line or a road to an underdeveloped region, one might want to consider the degree to which rail or road will stimulate the local economy. "The higher cost system may be more usable, more adaptable to the economy and the social organization of a country than the lower cost system. … If the high cost mode stimulates enough production to more than compensate for its higher transportation cost, it is the better system.…Transportation costs by themselves are not the sole criterion of the relative advantages of the two systems. The total impact on the economy needs to be understood."(1)

One way of looking at the alternatives differently has been making a list of pros and cons for each alternative, a good example being the one presented here which was derived from the professional engineers of the British

(1) Newcomb, Robinson, and Ralph E. Rachel, "Road vs. Rail in Developing Countries," *Transportation Journal*, Vol. 3:4, Summer, 1964, p.37.

Transport Commission[2] (See Exhibit 1).

In recent years, economists and transportation specialists have broadened the list of criteria which they feel relevant in the choice between rail and road. In addition to cost there at least eight criteria are important.

First, the shadow price of the capital, i.e., the values of other alternative public investments, should be considered by the decision maker. In a capital-scarce country, a financial measurement such as Internal Rate of Return or Net Present Value of each of the alternatives has to be evaluated in order to increase the velocity of their money invested, thus maximizing the total benefit given the limited capital.[3] In a country with relatively more capitals available, the long-run interest rates may be applied to the public investment.

Second, the nature of the commodities to be transported should be properly considered in the cost analysis. For example, some agricultural products are highly seasonal and dependent upon timing of delivery. Thus, the price fall due to delay in delivery of the commodities might more than offset the shipping cost differential. Other example might be perishable products or spare parts.

Third, each transportation mode has different levels of service in terms

(Exhibit 1) Comparison of Advantages Between Rail and Road

Rail	Road
1. Direct route	Cross country route
2. Heavy flows	Light flows
3. Long distance	Short distance
4. Direct rail access	No easy access to rail
5. Mechanized handling	Personal handling
6. Heavy bulk	Smaller bulk
7. Robust commodities	Fragile commodities

of time and handling. Road is generally faster and provides door to door delivery, cutting down loading and unloading times. Also there is less bureaucratic involvement in the road business which is so time-consuming.

(2) Mutsaers, Anthony, "Roads v. Rails in Developing Nations ... A New Look," *Transportation Journal*, Vol. 8:56-60, Winter, 1968, p.56.

(3) This can be proven by Irving Fisher's monetary equation $MV=PT$ where M is money, P is price, V is velocity, T is transaction and PT is gross revenue.

This service time difference will vary the levels of moving inventory which can be a substantial part of the shipper's cost.[4] In handling the freight, road again seems to have better performance with less pilferage and breakage than rail.

Fourth, flexibility of the scheduling can cause a shipper to favor one mode over another. The trucking business has no or loose schedules, and they can be easily adjusted to the request of the shippers. Also trucks can offer higher time reliability allowing specific commodities to arrive at a specific time at a certain place because of the smaller size of the truck load than the car load.

Fifth, import substitution of the equipment of transportation modes becomes a critical factor to a country which is conscious of the balance of payment. The opportunity price of the imported equipment might be higher than the nominal price in a country with a deficit balance. In such case, the real foreign exchange rate prevailing in the black market may be substituted for the official rate as .different alternatives are evaluated. If the size of the foreign currency requirements is big enough to influence the black market rates, the relevant foreign exchange rate will be even higher.

Sixth, the impact of transportation modes on local economy may be an important issue for the governments in less developed countries. For example, trucking business will decentralize the social structure along the highway by creating service station, garage, restaurants and others. Instead, railroad will formulate a fewer but larger communities around the depots. The history of the regional development in Canada along the railway system may be a good example. An issue in favor of road is that the trucks bring the market to the farmer, while with rail, the farmer will have to come to the market.

Seventh, the climate of the managerial skills may vary. Railroad is controlled by a single or a few number of head-quarters, and the personnels tend to develop bureaucratic personalities. On the contrary, a truck can be owned by an independent person who carries multiple functions as a driv-

---

(4) For a detailed analysis, see Appendix D of *The Economics of Competition in the Transportation Industries*, by John R. Meyer, Merton J. Peck, John Stenason, and Charles Zwick, Cambridge, Massachusetts: Harvard University Press, 1964, pp. 348-53.

er, purchaser, seller, broker, and entrepreneur.(5)

Finally, military strategic considerations are also raised in a country such as Korea. Transportation performs an indispensible role in an emergency as it did in the past Korean War. Highway seems to have a decisive advantage over rail in this regard. For example, highway can be easily converted to a landing strip for the aircraft in emergency.

Each of the above arguments describes a certain aspect of a huge elephant. However, there is no way of making an exhaustive list of these issues. Also, these item by item analyses without a proper estimation of the weight or the magnitude of the issues involved will lead the decision maker to falsely belive that as more *number* of the issues are raised against a specific alternative, it should not be adopted even if it has a single merit which can more than compensate all these disadvantages.

John R. Meyer and others developed a model in order to systematically evaluate the cost structures of different transportation modes.(6) The rational behavior of the shipper to minimize the total transportation cost was assumed. The total cost was composed of the fare charged by the transporter and the inventory cost on moving items which was incurred by the shipper. Then the total cost was compared between a pair of competitive modes of transportation in terms of per shipment of the shipper. For the pair railroad versus trucking, the long-run marginal cost of railroad and the full cost of trucking were used because of the nature of the trucking cost which does not include the proper share of the highway construction and maintenance cost, and because of substantial indivisibilities and scale economies in the railroad operation. Consequently, further adjustment was required in case railroad happened to be a favored mode over highway.(7) This model concerns the railroad pricing and does not directly show the governmental decision maker the economy of the total system.

Ann F. Friedlaender applied the model presented by Meyer in order to find the break-even points among three competing modes; rail, piggyback and trucking. The value of the commodities to be shipped and the size of shipment were evaluated for the sensitivity analysis respectively. Each of

(5) Mutsaers, *op. cit.*, p. 60.
(6) Meyer, *op. cit.*, p. 146.
(7) Meyer, *op. cit.*, p. 147.

them was assumed to affect the transportation cost structures of different modes, and consequently, the most efficient distances. She also took an assumption of Economic Ordering Quantity proposed by Meyer in his model. This is a reasonable assumption if sufficiently large number of shipment warrants the law of large numbers and proximity of the actual shipment size to the economic ordering quantity.[8]

Still, her model does not answer the question, "Which is a better alternative on a certain route, rail or road?" The following criticisms are mentioned.

First, the model considers the transportation structure from a shipper's point of view. Thus, marginal cost is applied in comparing the different alternatives. In the long run however, fixed cost becomes controllable and constitutes a part of marginal cost. Transportation investment has to be based on the long-term evaluation, and long-run marginal cost should be considered instead.

Second, the size of shipment and the value of the commodities are assumed to be independent and affect the cost structures of the different transportation modes respectively.[9] Nevertheless, Meyer's inventory model is based on the following causal relationships among the variables.

Independent Variable	1st. order *Variable*	2nd. order *Variable*
Expected yearly sales in physical units Unit cost of required merchandise Ordering cost Annual storage cost per unit Interest, risk, obsolescence	⇒Economic ordering ⇒ quantity	The rail rate which makes the shipper indifferent between use of truck or railway trans portation

It is clear that the quantity per shipment is influenced by the unit cost of the commodities to be shipped. The rationale of Friedlaender is not logically wrong, since the economic ordering quantity still has degrees of freedom and can be altered by changing the other variables in the model. However, the model lacks the intuitive power. Probably a better way of presenting the analysis is by taking the two independent variables, namely the unit cost of the commodities and the expected yearly sales, and use

(8) Cho, Dong Sung, "Inventory Order Quantity——An Heuristic Approach," unpublished paper, 1974.

(9) Friedlaender, Ann F., *The Dilemma of Freight Transport Regulation*, Washington, D.C.: Brookings Institution, 1969, p. 42.

them to evaluate the break-even points in terms of the most efficient distances. This alternative is proper especially when social cost benefit analysis is performed in aggregate terms.

Third, the model is based on per shipment. In fact, there will be a various mix of shipment over a given route and over a long period of time.

Finally, the model does not incorporate the other socio-economic dimensions which deserve closer attentions.

The review of the present state of the art, if not science, in the decision making process of the transportation investment, suggests us that a more comprehensive and systematic tool is needed to the governmental decision maker for a reliable analysis.

One of the currently available technique is the case-by-case approach. In each case, quantifiable aspects are evaluated first, and the sound judgment on subjective aspects either reinforces or attenuates the rationale of choosing one among various alternative proposals on the investment in transportation system.

Recently a comprehensive technique of decision making called Multi-Attribute Decision Analysis[(10)] has been developed and applied to various projects which incorporate both quantitative and qualitative criteria.[(11)] This technique can be a very powerful tool in the transportation problems as far as reliable sources of information are available. In the next chapter, a case on the Korean transportation system is presented and the application of Multi-Attribute Decision Analysis is discussed.

III. A CASE ON KOREAN TRANSPORTATION SYSTEM

In 1968, the Department of Transportation of Korea concerned with increasing the present transportation capacity between Seoul and Kangwon Province.[(12)] Kangwon's major industries have been coal mining and cement production, and most of these products are shipped to Seoul, the largest

---

(10) Alternatively, it is called Multi-Objective Decision Analysis.

(11) Keeney, Ralph L., and Howard Raiffa, *Multiple Objectives and Value Tradeoffs*, unpublished draft, May 1973. See Chapter 8, Airport Development for Mexico City: A Case Study for the application of the technique.

(12) Presidential Secretariat, *Research Report for Improvement of railroad operation and management*, Seoul, Korea, 1968, p. 131.

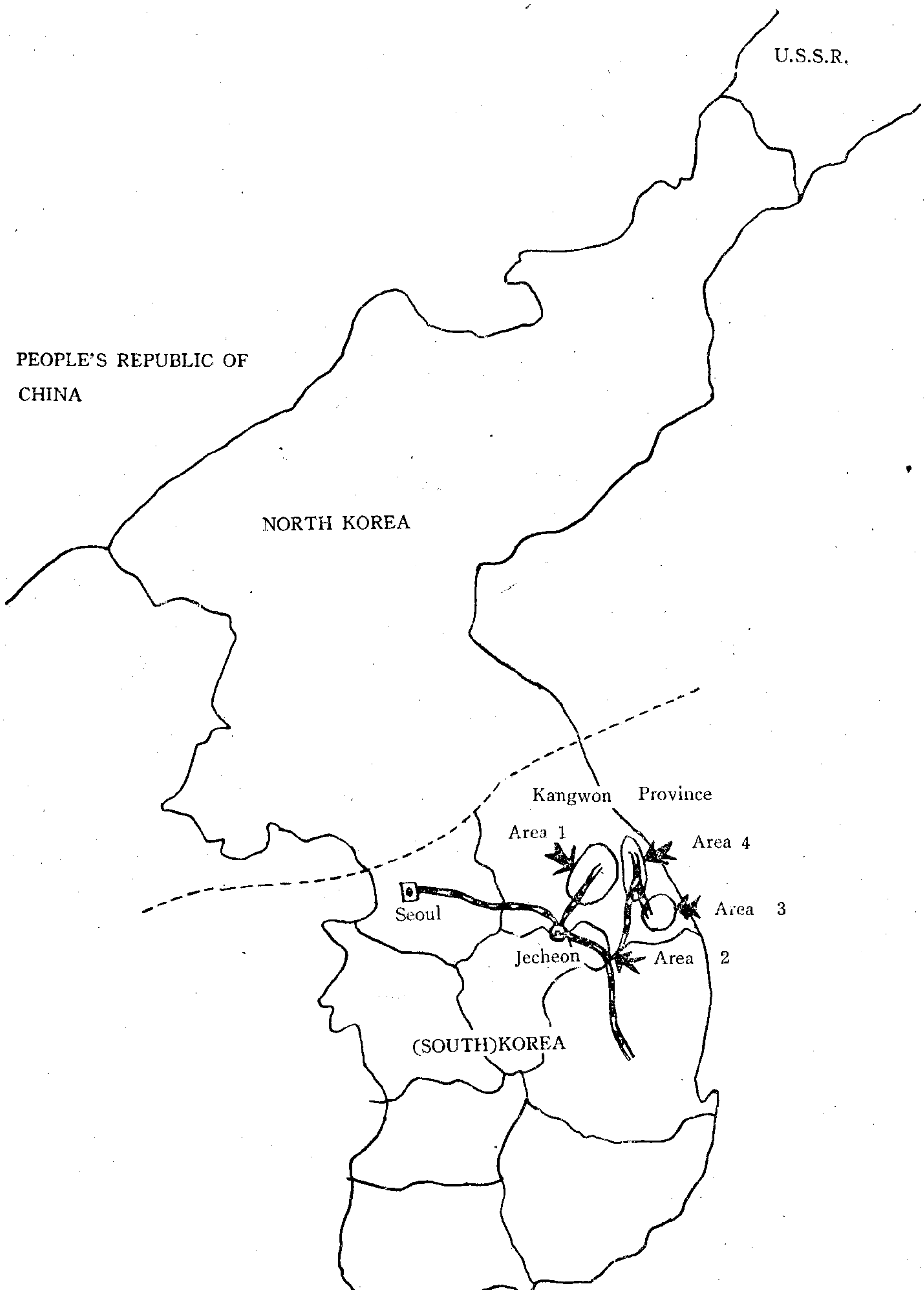
consuming city in Korea with a population of over seven million. In the next three years the national plan called for increasing Kangwon coal and cement production by 10% and 146% respectively (See Exhibit 2). The projection of the freight demand to Seoul from Jecheon which is a collecting point of the products in Kangwon Province is shown in Exhibit 3. The freight demand for backhauling in this route was almost negligible.

Kangwon Province is a mountaineous area and construction of transportation facilities is extremely difficult. The existing road, not highway, had only two lanes (one in each direction) and its capacity was further restricted by sharp curves, steep grades, and bridges which could only support 3-ton trucks. The highest maximum speed limit was 50km per hour (or 31 miles per hour). The rail line had many constraints as well. It was single track over the distance of 150km between Seoul and Jecheon. More than half of the total length of the rail had the steep grade of more than 10/1,000,[13] 33.5% of the accute circles in the line had the radius of 400 meters or less. Also, the tunnels stretched over 8% of the total length. A typical example was Chook-nyung Tunnel which had an extension of 4.5km with the radius of 400 meters and the grade of 25/1,000. Thus, the railroad operation between these two points was restricted by various engineering limits such as number and horsepower of locomotives per train, gross vehicle weight, number of units of a train, and the use of the dispersed

(Exhibit 2) Production Schedule of Coal and Cement in Kangwon Province (unit: 1,000ton)

		1968	1971	1976	1981
Coal	Area 1	2,810	3,110	4,260	4,400
	Area 2	150	170	100	150
	Area 3	2,470	2,700	3,050	3,100
	Area 4	3,920	4,320	4,930	5,160
	Total	9,350	10,300	12,440	12,910
Cement	Area 1	1,100	1,700	1,700	1,700
	Area 2	800	4,000	4,000	4,000
	Area 3	—	—	—	—
	Area 4	2,410	4,910	4,910	4,910
	Total	4,310	10,610	10,610	10,610

(13) The Department of Transportation, *Transportation White Paper*, Seoul, Korea, 1971, p. 124.


U.S.S.R.
PEOPLE'S REPUBLIC OF
CHINA
NORTH KOREA
Kangwon Province
Area 1
Area 4
Area 3
Area 2
Seoul
Jecheon
(SOUTH)KOREA

(**Exhibit 3**) Transportation Demand Between Seoul and Jecheon (unit: 1,000ton or people)

Jecheon→Seoul		1968	1971	1976	1981
Freight	Coal	4,780	5,600	5,600	5,600 (42.8%)
	Cement	2,460	5,000	5,000	5,500 (42.0%)
	Others	600	940	1,700	1,990 (15.2%)
	Total	7,840	11,540	12,300	13,090(100.0%)
Passenger		2,012	2,523	3,000	3,000
Seoul→Jecheon					
Freight		minimal	minimal	minimal	minimal
Passenger		2,012	2,523	3,000	3,000

power system(14)

The government was primarily concerned with the transportation of the basic materials produced in Kangwon Province. Especially coal was the prime source of energy and the delivery of coal to Seoul area in the winter time was one of the important issues of the Transportation Department. Consequently, most of the passenger transportation was taken care of by privately owned bus companies, while the nationalized railroad system played the dominant role in freight transportation up to its capacity of the railroad and the conversion of the freight demand to the train equivalent are shown in Exhibit 4.

The Department of Transportation developed the following alternatives to increase the capacity of the freight transportation in this area for the coming 13years.

(**Exhibit 4**) The Capacity of and The Demand for Railroad
(unit: frequency of trains per day)

	Capacity	Demand			
	1968	1968	1971	1976	1981
Jecheon→Seoul	20	32*	47	50	54

* Based on 34 Box cars or gondolas with 20 ton capacity each, 365 day operations.
7,840,000/365=21,480ton (daily demand)
21,480/(20×34)=32 (daily frequency of train)

(14) The use of the dispersed power system is critical in most Korean railroad because of the steep grade. Generally, this system has advantages of cost reduction, increased speed and safety of long trains, and increased traffic flexibility. See Cummins Report on Railroad Industry, 1974, p. TL-05-04, for the details.

Alternative 1: Construct highway between Seoul and Jecheon.

Alternative 2: Construct the second rail line between Seoul and Jecheon to make it double-track.

Alternative 3: Electrify the railroad between Seoul and Jecheon.

The cost of construction and operation for each alternative is shown in Exhibit 5.

There were various alternatives other than the three just mentioned. Installation of CTC System (Centralized Traffic Control System) was an obvious one, and partial layout of double-track where necessary was another. Since none of these were estimated to have the capacity to satisfy the freight demnad in the target year of 1981, the officials excluded them from the list of alternatives.

Because of the high investment expenditure involved in construction of the highway, Alternative 1 was eliminated at the initial stage. The other two were compared against each other and Alternative 3 was chosen by Department because of less construction and operating costs required. One of the hidden reasons of eliminating Alternative 1 might have been because the Department of Construction was in charge of high-way construction and the Deparment of Transportation would be reluctant to evaluate the proposal which would increase the share of the governmental investment

(Exhibit 5) Investment and Operating Cost (unit: million Won)

	Alternative 1	Alternative 2	Alternative 3
Investment			
Construction	60,000	15,000	2,700
Equipment Cost	—	5,050	3,276
Others	—	623	623
Total	60,000+	23,673	6,599
Operating Cost*			
Power Cost	Not Available	754	590
Equipment Maintenance	Not Available	227	118
Road Maintenance	Not Available	533	37
Depreciation	Not Available	791	195
Investment interest (6%)**	Not Available	1,254	396
Total		3,561	1,338

* Operating cost is based on the capacity to meet the demand in 1981.

** The figure represents 6% of the total investment.

of the other department.

IV. APPLICATION OF MULTI-ATTRIBUTE DECISION ANALYSIS

Considering various impacts of the transportation modes to economy and society, more systematic and comprehensive evaluation should have been required by the decision maker, other than the comparison of immediately identifiable costs, in the case of transporation system between Seoul and Jecheon. As discussed in Chapter II, Multi-Attribute Decision Analysis could have been a proper analytic tool if it had been applied to the problem using a reliable source of informations. Reliability of an information source is crucial, since this analysis requires substantial amount of subjective judgment of the decision maker. I was able to collect relevant informations on quantitative data regarding the case from various materials both published and unpublished. Unfortunately however there was no way for me to get an access to the value judgment of the decision maker of the issue at the time. Even if I met him, he might be a different person than he was at the time of decision making. For the sake of analysis alone, I resorted to a subject who is quite knowledgeable in the recent social and economic conditions and the transportation system of Korea. This way of avoiding the difficulties of getting a reliable subjective judgment will penalize the researcher in terms of the accuracy of the solution of the problem. Nevertheless, it will suffice for the purpose of demonstrating the application of Multi-Attribute Decision Analysis to a specific case in this paper. For the remaining part of this chapter, the process of applying this technique to the case of transportation system between Seoul and Jecheon will be discussed in detail. Then we will be able to see how much the recommendation with the help of this technique differs from the actual decision made by the government.

1. Defining Objectives and Attributes

The first step of Multi-Attribute Decision Analysis is to define the set of objectives which is considered to be relevant to the problem by the decision maker. Scrupulous judgment is required in selecting these objectives in order to avoid possible multicolinearity between the objectives. Then, a proper attribute for each objective variable should be identified. If an attribute which directly measures the objective value is hard to idnetify, a proxy attribute which reflects the degree to which an associated objective is met can be used.(15)

I asked the subject to play the role of the decision maker who was the officer in charge of the final approval of the proposal presented by the Department of Transportation. Naturally, the final decision maker, probably the President of the nation, should be concerned with the total social cost and benefit for the whole nation rather than the departmental objectives. I provided him with the relevant informations which were believed to be available to the decision maker in 1968. Then I asked him of his objective or objectives on the issue. He immediately replied with the following statement. "First sufficient capacity of transportation to meet the freight demand for the next ten years or so. Second, minimization of the cost of construction and operation of transportation system." After considering the other aspects of the problem commented by the researcher, the set of the objectives and the proper attributes which were thought to indicate the level of these objectives were determined by the subject. (See Exhibit 6) Each of these objectives is discussed below.

i. Governmental Investment

The governmental insestment (symbolized by C1. Each of the objectives will be symbolized by Ci.) was chosen because all the railroad system was nationalized, and hence, construction of both railroad and highway was to be financed by the government. The government has been using deficit finance extensively for the economic devolpment plans, and the required amount of investment exceeded the size of the budget each year. Total governmental investment in 1968 amounted to 421 billion Won(16) of which 95 billion Won or 22.5% was allocated to the transportation area. The total amount of the governmental investment for each alternative (symbolized by X1. Again, each attribute is symbolized by Xi.) was decided as a proper attribute without any argument.

---

(15) Keeney, R., and H. Raiffa, *Decision Analysis with Multiple Objectives*, unpublished draft, March 1974, p.2-48.

(16) Won is a monetary unit of Korea. Exchange rate of Won with U.S. Dollar on January 1st., 1968 was 274:1.

(**Exhibit 6**) The Objectives (Ci) and The Attributes (Xi)

I. Applicable to the Government
- C1: Minimization of the governmental investment for construction of the transportation system between Seoul and Kangwon Province (X1: Total investment cost)
- C2: Minimization of the use of foreign currencies (X2: Total foreign currencies required)
- C3: Effectiveness of transportation during the war time (X3: Subjective judgment by the decision maker)

II. Applicable to the public and the shippers
- C4: Capacity to meet the freight demand in 1981 (X4: % capacity over demand)
- C5: Balance of the transportation system(X5: Number of transportation modes)
- C6: Minimization of the social shipping cost (X6: Total annual cost of transport operation and shipping inventory)

III. Applicable to the local community
- C7: Maximum impact on stimulation of the local development (X7: Subjective judgment by the decision maker)

ii. Foreign Currency Requirement

The amount of foreign currencies required (C2) was another constraint to the Korean government because the balance of payment has never shown black letters in the entire history of the Republic of Korea. The government has always had problems with the level of foreign exchange reserve. The government officials considered the use of foreign aid such as AID fund, but the chance of acquiring the substantial portion of the budget from such institution was slim at the time. Total amount of foreign currency requirement (X2) was chosen as a proper attribute.

An alternative to the inclusion of C1 and C2 is worth nothing. If the government restricts foreign exchange and the dual foreign exchange system exists in the economy, evaluating the total investment costs with the use of a black market exchange rate (not an official rate) for the portion of foreign currency requirement will give the decision maker a reasonable estimation of both C1 and C2. However, the Korean government adopts the floating system of foreign exchange with a combination of the quota and the prior approval systems. Thus, it was regarded as necessary to include both C1 and C2 separately in the set of the objectives.

iii. Provision for War

Awareness of a war and the provision for such emergencies (C3) have been an indispensible criterion in any kind of governmental considerations in Korea. After the ceasefire in 1953 between South Korea and North Korea, both governments have been under constant fear of abrupt breaking of a war. As an illustration, South Korean government allocates nearly 30% of its budget on the national defense expenditure, while North Korean government spends 40% of the budget for the same purpose each year. Especially the recent collapse of South Vietnam and its video-tapes on the panicky struggles for survival of the Vietnamese along the highways and in the cities shocked the South Korean people as they realized the similarity of the political situations in Vietnam and in Korea, and as they pictured the probable aftermath in case of such national crises. Thus, potential availability of the transportation system to the refugees and the troops should be considered as one of the important objectives in the planning of the government. However, the difficulty of estimating potential availability of the transportation system during the war forced the subject to use the subjective judgment of himself (X3) on that matter as an attribute.

iv. Capacity of Transportation

The capacity of transportation to meet the demand for the planned period (C4) was the primary cause for the Department of Transportation to raise the whole issue of improving the present transportation system between Seoul and Kangwon Province. The year 1981 was selected as the target year by the government because the Fourth Economic Development Plan ends on that year. By that time, per capita income was expected to reach $800 which was regarded as an indication of a national economy being in the middle advanced group in the world. The ratio of the capacity over the projected demand (X4) was decided as an attribute for this objective.

v. Balance of Transportation System

Balanced transportation system was considered to be (C5) favored by shippers because it would provide them with a fair intermodal (and also, publicly operated rail versus privately owned trucking) competition and more flexibility of the shipping schedules. The number of transportation modes between the two points (X5) was chosen as an attribute. Though relatively simple, this proxy attribute was thought to be a fairly reliable indicator of the balance of the transportation system.

vi. Minimization of the Social Transportation Cost

Minimization of the social transportation cost (C6) was included in the set of the objectives because it would reflect the economy of society related with transportation activities. There are two components in the social transportation cost; one is the transport operating cost, the other is the shipper's inventory cost. The operating cost which is based on the marginal cost of transport operation would be transferred to the shippers in the form of the user charge. The inventory cost is important to the society in general as well as to a specific shipper. The more the society has its material resources in the form of inventory in the deterministic state with a certain demand schedule, the slower the velocity of these resources will be, and the smaller their use will be to the society.

The summation of the operating cost incurred by the transporters and the inventory cost incurred by the shippers (X6) were chosen as an attribute of the social transportation cost. An easier figure to understand might be the total cost incurred by the shippers which includes both actual fare charged by the transporters and the inventory cost. It requires an assumption that transporters will charge the fares based on the marginal costs. In this case, coal is the prime source of energy in Korea, and coal mining, coal transporting and coal processing were all subsidized by the government. Thus, the actual fare charged to the freight of coal might be substantially lower than the marginal cost, and does not necessarily reflect the total social cost of transportation.(17)

A corollary objective to the social cost might be the social benefit using the value added by transportation activities as an attribute. This may bring a paradoxical problem. For example, by limiting the transportation of a certain commodity to a market, or by charging higher transportatron fare for a demand inelastic commodity, the value added by the transportation function will increase. This distortion does not indicate the increase of social benefit. Probably, the social benefit may be properly explained with the concept of consumers' surplus. However, the size of the consumers' surplus is determined by the demand and supply curves and their shifts, and the difficulties of projecting these curves and analyzing their sensitivities led the subject to use the social cost without the social benefit as the objective.

---

(17) For detailed discussion of the government practices on pricing transportation, see Prest, A.R., *Transport Economics in Developing Countries*, New York: Frederick A. Praeger, Publishers, 1969, pp. 52-63.

vii. Stimulation of the Local Development

Finally, stimulation of the local development (C7) was included. Kangwon Province is mostly composed of rural communities which depend on agricultural production and which do not have much economic and social mobility as larger cities do. The system of local self-government was not yet established in Korea and the task of local economic development had been one of the difficult problems to the central government. Again, the subjective judgment of the decision maker(X7) was chosen as an attribute because of the difficulty of defining a proper scale of measuring the stimuli provided by various modes of transportation.

viii. Other Considerations

Other potential objectives were also evaluated by the subject.

First, speed of the transportation mode should have been one of the major objectives if the commodities to be transported had been such items as vegetables or spare parts which highly dependent on the speed of the delivery. The fact that more than 90% of the transportation demand from Jecheon to Seoul is composed of coal and cement which are rather insensitive to the speed of the delivery allowed the subject to exclude the speed from the set of the objectives. Certainly, the speed of the transportation modes is reflected positively by the inventory cost which constitutes the total social cost of transportation.

Potential development of the managerial skills and entrepreneurship was also considered. Since Koreans are provided with a relatively good professional education system, exclusion of this objective was thought to be rather insensitive to the overall evaluation.

2. Estimating the Potential Outcomes of the Attributes

In the second step of the application of Multi-Attribute Decision Analysis, the potential outcomes of the different alternatives are represented by those attributes previously defined.

Information on the total investment cost (X1), total foreign currencies required (X2), and percent of the transportation capacity over the demand (X4) were readily available from the published source. Since all the alternatives are designed to have the capacities to meet the demand in 1981, C4 and X4 can be safely deleted from the consideration without affecting the final solution.

X5 is simply the number of transportation modes. Since the present road is not adequate for the trucking business between Seoul and Jecheon, the second and the third alternatives will be assumed to have only one mode of transportation, rail. For the first alternative two modes will be available which are rail and road.

From the past experience during the Korean War, it was remembered by the subject that the railroads were not particularly available as a means of transportation. In a panic circumstance few operators were on duty and a minor damage on a track would often block the whole rail operation for a long while. On the other hand, the highway will be also blocked if one of the highway bridges is blown up. In general, highway seemed to be less subject to the total blockage in such circumstances. Some highways in the other regions of Korea are designed to be converted to landing strips for aircraft. Certainly, the advantages of highway can become the advantages to the otherside once the area is captured by them. Overall, road seemed to be better than rail in this regard by the subject. Between Alternative 1 and 2, he thought that a double track rail might be slightly better than a single electric rail in these circumstances.

Impact of the different transportation modes on stimulation of local development was difficult to define and to estimate. Nevertheless, it was clear to the subject that highway has more access to the rural communities. With the highway they will have an access to Seoul, and become the suppliers of agricultural products of the city which is the world's eighth largest metropolis. Especially Koreans are mostly vegetarians, and the fact that the consumption of pickled cabbage which is a major component of "Kim-chi", a Korean sort of bread and butter, exceeds 20% of the total food expenditures provides the residents in the vicinity of the highway with an excellent chance for increasing their incomes. Also the highway can provide these people with the opportunities of operating service industry such as restaurants and gas stations. Furthermore, the residents in this area will be able to see the cultural flows from the urban areas more directly, break the traditions of inertia, and build the spirit of self-development. Altogether, road again seemed to be better than rail.

Calculation of the total annual cost of operation and inventory needs careful treatment because of its direct and explicit relevance to the people involved in transportation. The total cost can be derived by the following equations.

$$C = CO + CI$$
$$= COD + COI + CIS + CIC + CIO$$
$$= (CODE + CODL) + (COIM + COID + COII) + CIS + CIC + CIO$$

C: Total annual cost
- CO: Total cost of operation by transporters
  - COD: Total direct cost of operation
    - CODE: Energy cost including oil and electricity
    - CODL: Labor cost
  - COI: Total indirect cost of operation
    - COIM: Maintenance cost
    - COID: Depreciation cost
    - COII: Interest charge on investment
- CI: Total cost of inventory by shippers
  - CIS: Storage cost
  - CIC: Inventory carrying cost
  - CIO: Inventory ordering cost

The figures of the total cost of operation were available from the Department of Transportation. The Department, however, did not consider the cost of inventory incurred by the shippers. This consideration seemed to be beyond the current level of any governmental decision making process, as in this case.

The storage cost and the inventory ordering cost might be negligible in this particular case. The demand of coal reaches the peak in late fall and winter, while the demand of cement reaches the peak in early spring through early fall. The supplies of coal and cement are constant throughout the year. By combining these two commodities which constitute 42.8% and 42.0% respectively in 1981, the transportation scheduling can be smoothed out. Thus, the inventory provision for the seasonal demand of coal and cement can be maintained at a minimum level within Seoul City where the inventory storage cost is comparatively high, and most volumes will be transported from Kangwon Province according to the requirements planning. All the rest inventories will be maintained in Kangwon Province where the storage cost is insignificant. Also, the inventory ordering cost can be excluded from the calculation of the total inventory cost without distorting the real cost figures. The transactions of coal and cement may involve huge volumes of commodities, and the ordering cost will be negligible. The exclusion of the ordering cost has a particularly important meaning to the analysis.(18) Now the assumption of Economic Ordering Quantity is no more necessary. Instead, it can be assumed that the transportation scheduling is solely determined by demand and economy of scale of the transportation.(19) The demand of coal and cement will be based on requirements planning which is proposed by Thurston(20) as the best inventory control system in a deterministic situation.

Exhibit 7 shows the potential outcomes of the attributes for each alternative.

(Exhibit 7) Potential Outcomes of the Attributes

	Alternative 1	Alternative 2	Alternative 3
X1: Governmental Investment	₩60 billion	₩21 billion	₩6.6 billion*
X2: Foreign Currencies	—	—	$19.4 million
X3: War-time Effectiveness	Very Effective	Medium	Useless
X4: Capacity	Sufficient (over 100%)	Sufficient (over 100%)	Sufficient (over 100%)
X5: Balance	2	1	1
X6: Social Cost**	₩6,407 million	₩3,914 million	₩1,684 million
X7: Community Stimulation	Very Effective	Minimal	Minimal

* The investment for Alternative 3 is divided by the following:
Domestic capital: ₩1.2 billion
Foreign capital: $19.4 million × 275 = ₩5.4 billion
total: ₩6.6 billion

** See Exhibit for the calculation of Social Transportation Cost.

(18) Exclusion of the ordering cost forces the economic ordering quantity to be zero from the simple deterministic model:

$$Q^*=\sqrt{\frac{2RS}{pk}}=\sqrt{\frac{2R(0)}{pk}}=0.$$

This suggests that the transportation schedule should be strictly based on the demand.

(19) Economy of scale of the transportation indicates the shipment by train load. One train load is composed of 34 units of 20-ton gondolas or boxcars for the line Seoul to Jecheon. This number of units is limited by engineering constraints on the track, such as grades and curves.

(20) Thurston, Philip H., "Requirements Planning for Inventory Control," *Harvard Business Review*, Vol. 50, No. 3, May-June 1972, pp.67-71.

(**Exhibit** 8) Calculation of The Social Transportation Cost

	Alternative 1	Alternative 2	Alternative 3
I. Cost of Operation			
Cost/ton/Km (Won)	Rail: 1.8 Road: 4.0	Rail: 1.8	Elec.Rail: .7
Distance (Km)	150	150	150
Annual Volume (ton)	Rail: 4.85million* Road: 8.24million	Rail: 13.09million	Rail: 13.09million
Total cost of operation (Won)	6,254million	3,561million	1,338million
II. Cost of Inventory	Road	Rail	Elec. Rail
Delivery time: Loading	6 hours	3 days	3 days
Haul	3 hours	6 hours	3 hours
Unloading	6 hours	3 days	3 days
	15/24/365	6.25/365	6.125/365
Weighted Price/ton (Won)	5,244**	5,244	5,244
Inventory carrying cost per year as % of price	30%	30%	30%
Annual Volume (ton)	Rail: 4.85million Road: 8.24million	Rail: 13.09million	Rail: 13.09million
Inventory carrying cost(Won)	153million	353million	346million
Inventory storage cost	minimal	minimal	minimal
Inventory ordering cost	minimal	minimal	minimal
Total cost of inventory (Won)	153million	353million	353million
Total Social Transportation Cost (Won)	6,407million	3,914million	1,684million

* The rail capacity in 1968 is assumed to remain unchanged in 1981.

** Weighted price of the freight is based on 1968 wholesale prices of the following commodities.

Coal	3,560×42.8%=1523.7
Cement	7,700×42.0%=3234.1
Others (Iron ore)	3,200×15.2%= 486.4
	₩5244.2

3. Assessing utilities for the outcomes

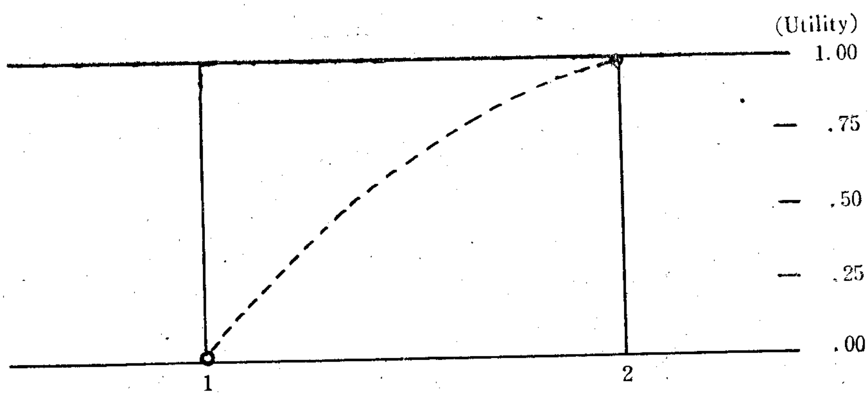
After the levels of the attributes for each of the alternatives are estimated, utilities have to be assigned for them. The decision maker's subjective assessment on the level of preference of the results is necessary in order to assign the values of utility to the attributes.

For an attribute which is continuous in its nature, it is necessary and desirable to construct a utility function over a continuous range of the attribute. Total investment cost (X1), total foreign currencies required (X2), and the total annual cost of transport operation and inventory (X6) fall under this category.

For an attribute with a discrete scale, the utility function will be also discrete. Subjective judgment is derived using a few discrete values such as excellent, good, fair and poor, but the nature of the subjective judgment can be continuous from excellent to poor. For this reason, the utility curve can be smoothed for the subjective judgment.

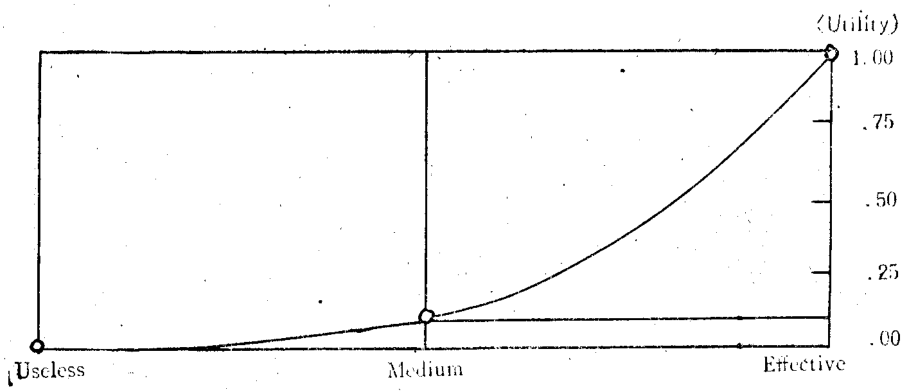
Using the techniques explained in Appendix B, the utility curve of the subject for each of these six attributes has been developed and shown in Exhibit 9 through 14.

(Exhibit 11) The Utility Curve of X3 : War Time Effectiveness



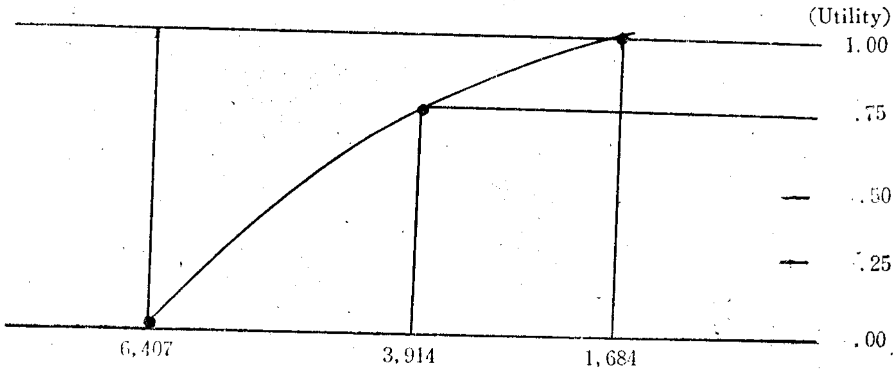
(War time effectiveness: Subjective judgment)

(Exhibit 12) The Utility Curve of X5 : Balance of Modes



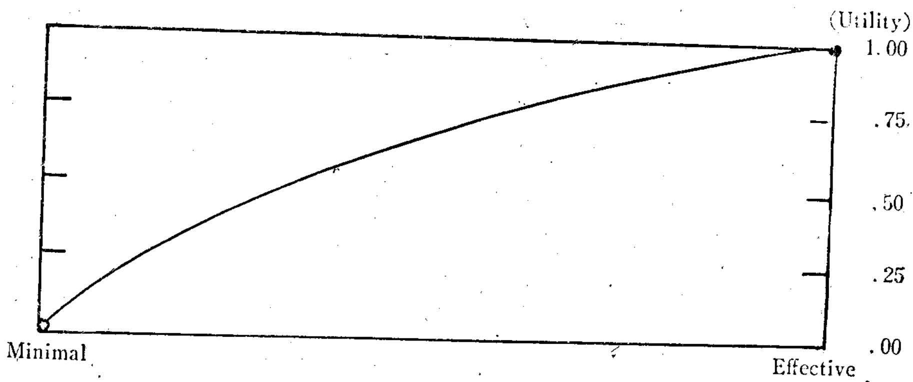
(Balance : number of transportation modes)

(Exhibit 13) The Utility Curve of X6 : Social Cost



(Social cost : million Won)

(Exhibit 14) The Utility Curve of X7 : Community Stimulation)



(Subjective judgement)

4. Measuring the Relative Importance of the Attributes

From the above six curves, the utility function of each alternative has been developed as following.

$U(A1)=(X1, X2, X3, X4, X5, X6, X7)$

$=U$(₩60 billion, \$0, Effective, 2, ₩6,407 million, Effective)

$=k_1U_1$(₩60 billion)$+k_2U_2$(\$0)$+k_3U_3$(Effective)

$+k_5U_5(2)+k_6U_6$(₩6,407 million)$+k_7U_7$(Effective)

$=k_1(0)+k_2(1)+k_3(1)+k_5(1)+k_6(0)+k_7(1)$

$U(A2) = U($₩21 billion, \$0, Medium, 1, ₩3,914 million, Minimal$)$

$= k_1 U_1($₩21 billion$) + k_2 U_2(\$0) + k_3 U_3($Medium$)$

$+ k_5 U_5(1) + k_6 U_6($₩3,914 million$) + k_7 U_7($Minimal$)$

$= k_1(.75) + k_2(1) + k_3(.10) + k_5(0) + k_6(.75) + k_7(0)$

$U(A3) = U($₩6.6 billion, \$19.4 million, Useless, 1, ₩684 million, Minimal$)$

$= k_1 U_1($₩6.6 billion$) + k_2 U_2(\$19.4$ million$)$

$+ k_3 U_3($Useless$) + k_5 U_5(1) + k_6 U_6($₩1,684 million$)$

$+ k_7 U_7($Minimal$)$

$= k_1(1) + k_2(0) + k_3(0) + k_5(0) + k_6(1) + k_7(0)$

k_i is the subjective weight of the attribute Xi. The issue in this step is how to measure the relative importance of the attributes or k_i's. By having these values the decision maker can avoid the direct comparison of multi-attribute values which normally conflicts against each other. It requires, however, the assumption of the additive utility function which is shown by the following equations.

$$U(X1, X2) = U_1(X1, X2^0) + U_2(X_1^0, X2)$$
$$= k_1 U_1(X1) + k_2 U_2(X2)$$

There are two techniques available for the decision maker in order to find these k_i values; one is the lottery method and the other is the indifference curve method which are explained in detail in Appendix C. The latter one is easier to understand, but for the attributes with discrete scales, the former one is the only alternative. In this case, the lottery method is used to assess the values of k_3, k_5, and k_7. For the other values, the indifference curve method is applied. According to the subject's assessment, the following values are determined to be appropriate for the calculation of the single objective value.

$k_1 = .09$

$k_2 = .03$

$k_3 = .20$

$k_5 = .15$

$k_6 = .33$

$k_7 = .20$

5. Deriving a Single Utility Value for Each Alternative

The calculation of the single utility value from the values which the subject assessed is rather straightforward. For each alternative, the resulting utility value is as follows.

$$U(A1) = .90(1) + .03(1) + .20(1) + .15(1) + .33(0) + .20(1)$$
$$= .03 + .20 + .15 + .20$$
$$= .58$$
$$U(A2) = .09(.75) + .03(.1) + .15(0) + .33(.75) + .20(0)$$
$$= .0675 + .03 + .02 + .25$$
$$= .3675$$
$$U(A3) = .09(1) + .03(0) + .20(0) + .15(0) + .33(1) + .20(0)$$
$$= .09 + .33$$
$$= .42$$

From the comparison of these values, it is clear that Alternative 1 is indeed the best alternative, Alternative 3 is the distant second, and Alternative 2 is the last.

V. CONCLUSION

From the analysis above, we can see that the government might have altered the decision to electrify the railroad, if the decision maker had applied a more systematic technique and if he had seen the whole picture of the problem comprehensively.

It is often argued that railroad operation requires a certain length of haul in order to achieve economy of scale. The route between Seoul and Jecheon stretches over 150 km or 94 miles which does not seem to be long enough for rail operation. Our analysis recommends highway rather than rail. However, the rationale behind the recommendation is not of an economic consideration. In fact, economy of operation alone strongly favors railroad contrary to the common belief of diseconomy of scale of railroad on the short distance. It is the other factors that more than compensate the disadvantages of higher cost of truck operation. First, the Korean government is very much conscious of local development of this area which is one of the economically backward regions of the country, and highway construction seems to be a logical and reasonable alternative. Second, war-consciousness has been a major premise of the ordinary life styles of the people in Korea, and this consideration also gives a tip in favor of highway. Third, the balance of the transportation system may bring a fair competition between the different modes and give them a stimulus for better service which will ultimately result in sound management and efficient operation of the total transportation system. These considerations were given proper weights respectively, and they altogether exceeded the cost differentials, thus resulting a final recommendation on highway construction.

Certainly the analysis performed here may invite more criticisms than agreement because of the limited capacity of this writer. First of all, the reliability of the subject as a proxy personality for the actual decision maker has to be questioned. Since Multi-Attribute Decision Analysis partly based on the judgment of the subject, the sensitivity of the subject's attitude is crucial to the final solution. For example, by rearranging the values of k_1 and k_3 to .20 and .09 instead of .09 and .20, Alternative 3 easily becomes the optimal solution. Second, exhaustiveness of the alternatives has to be questioned. Only three alternatives are considered here. Still, there are many alternatives which deserve the decision maker's closer attention. For example, timing of the investment may be an important variable which can branch a score of alternatives. Also, combination of different alternatives such as highway construction and electrification of the railroad at the same time may be suspected as a better alternative.

In spite of these deficiencies of the analysis performed in the paper, it raises some points which have significant values conceptually and operationally to the decision maker.

First, the application of this technique will enable the decision maker to have the systematic point of view for the problem he is confronting, and let him define his own objectives comprehensively. Often, decision makers do not even consider what is the objective and tend to follow nearsightedly what is less significant to him. In most cases, the objective or objectives which the decision makers can and do identify are only those which are well formulated and easily conceivable, i.e., quantitative data such as investment and operating cost. The difficulties of understanding and formulating other qualitative aspects of the problem do not suggest irrelevance or uselessness of these variables to the decision makers. Thus, the first step of this analysis alone might give the decision makers an invaluable frame of reference.

Second, no one is sure of the validity of the subjective judgment of the decision maker. He would make mistakes because of the lack of knowledge and information on the problem, or because of his personal bias and prejudice. However, repetition of implementing this technique to the similar problems may give him a learning experience, and he will be able to correct himself and develop the prudence in his subjective judgment on the matters. And that is what the role of the decision maker s all about.

(Appendix A) TRANSPORTATION IN KOREAN ECONOMY

For the past decade Korea has emerged as one of the fastest developing countries in the world. The compounded annual growth rate of GNP was 9.5% for the period of 1962 to 1970 which marked the second highest growth rate in the free world next to Japan. The contribution of the transportation industry to the value added has been growing more rapidly than the growth rate of GNP with impressive 16.2% for the same period. Consequently, proportion of the value added by the transportation industry was increased from 2.68% of GNP in 1962 to 4.54% in 1970.(21) The governmental investment to the transportation sector also increased from 10.4 billion Won in 1962 to 178.8 billion Won in 1970 which accounted 25.1% of the total domestic investment by the government.(22)

There has been a change in the composition of the different transportation modes to the value added, characterized by the decreasing share of rail and the increase of road, shipping and air as seen in Exhibit 15. These trends are explained by the following observation.

First, the equipment of railroad has been fully utilized and there was no major replacement or addition while the demand for transportation has been growing steadily.

Second, the government placed high priority on highway construction.

(21) The Department of Transportation, *Transportation White Paper*, Seoul,Korea, 1971, p. 26.
(22) All the figures are by 1965 current price. In 1965 the foreign exchange rate was 262 Won to 1 U.S. dollars.

At the same time, big-sized diesel-engine trucks were being introduced. Thus, the marginal cost of trucking was lowered and the competition of road against rail was strengthened.

Third, big oil refineries have been constructed around the port areas of Korean Peninsula during the sixties, and marine transportation was requir- ed for moving bulky oils.

Finally, a privately owned airliner, Korean Air Lines (KAL) has been participating in golden routes such as Seoul-Tokyo-Los Angeles/San Franc- isco and Seoul-Taipei-Hongkong-Paris, and increased its market share over other international airlines. Electronic industry has been rapidly developing in Korea, and the production of high valued items also enabled the incre- ase of shipment by air.

The marine and airline industries are the natural outgrowth according to the new market demand, and do not seem compete against rail or road directly. The intermodal competition has been mainly between rail and road. In Korea, the operations of both rail and road are heavily dependent upon foreign manufactured equipment such as locomotives and diesel-engine tru- cks. Since government restricts the importation of the expensive equipment because of its lack of foreign capital reserve, the beneficiary should get the approval of the government. Thus, the orientation of the governmental

(Exhibit 15) Value Added by Transportation[23]

(unit : 1 million Won-1965 current price)

	1962	1965	1968	1969	1970
GNP (A)	634,970	805,850	1,127,320	1,306,190	1,422,330
Transp. (B)	17,012	27,003	48,150	57,190	64,575
Transp. (%)	100	100	100	100	100
Rail (%)	5,691(33.5)	7,628(28.2)	11,400(23.7)	12,022(21.0)	11,625(18.0)
Road (%)	6,408(37.7)	12,027(45.2)	22,720(47.2)	27,373(47.9)	31,142(48.2)
Marine (%)	1,898(11.2)	3,026(11.2)	6,790(14.1)	9,249(16.2)	12,121(18.8)
Air (%)	85 (0.5)	279 (1.0)	700 (1.5)	1,012 (1.8)	1,437 (2.2)
Storage (%)	906 (5.3)	1,456 (5.4)	2,550 (5.3)	2,982 (5.2)	3,244 (5.0)
Cargo Handling (%)	1,221 (7.2)	1,572 (5.8)	2,970 (6.2)	3,531 (6.2)	3,896 (6.0)
Others (%)	825 (4.6)	835 (3.2)	1,020 (2.0)	1,020 (1.7)	1,110 (1.8)
B/A (%)	2.68	3.35	4.29	4.37	4.54

(23) The Department of Transportation, *op. cit.*, p. 28.

policy plays a significant role in the competition between rail and road.

(Appendix B) A TECHNIQUE OF ASSESING UTILITIES

The subject was asked with the following question. "For attribute X1, I imagine that you consider the investment of 6.6 billion Won as the best and the investment of 60 billion Won as the worst. Then you can assign your utility value of 1 for the best case and 0 for the worst case. Now let's assume that you have two alternatives which have exactly the same results except that the first one requires 21 billion Won of investment for certain and the second one requires either 6.6 billion Won with a 50% chance or 60 billion Won with another 50% chance. Which alternative will you choose?" This proposal can be illustrated with the following notation:

$$21 \text{ billion Won } (?) \substack{> \\ \sim \\ <} \begin{cases} .5 & 6.6 \text{ billion Won } (1) \\ .5 & 60 \text{ billion Won } (0) \end{cases}$$

The subject replied, "Certainly I will choose the first one with the certain 21 billion Won investment." His preference can be shown as following.

$$21 \text{ billion Won } (?) > \begin{cases} .5 & 6.6 \text{ billion Won } (1) \\ .5 & 60 \text{ billion Won } (0) \end{cases}$$

His perference shows that the utility of 21 billion Won investment is greater than $.5 (= .5 \times 1 + .5 \times 0)$.

I asked again, "With what kind of probability assignment on 6.6 billion Won investment will you be indifferent between the two alternatives?" He posed, thought for a while, and came up with an answer of 75% for the best chance and 25% for the worst chance. Now, the tradeoff between the two alternatives as evaluated by him is:

$$21 \text{ billion Won } (.75) \sim \begin{cases} .75 & 6.6 \text{ billion Won } (1) \\ .25 & 60 \text{ billion Won } (0) \end{cases}$$

Now his preference shows that the utility of 21 billion Won investment is $.75 (= .75 \times 1 + .25 \times 0)$.

This result is shown in Exhibit 9 by the utility curve.

(Appendix C) TECHNIQUES OF FINDING ki VALUES

Two techniques are available; one is the lottery method and the other is the indifference curve method. The latter one is easier to understand, but the former one should be used for the attributes with discrete scales.

I. Finding ordinal rankings of k_i's

In order to get the ordinal rankings k_i's, ask the following question to the subject. "Which do you prefer between $U(X1^*, X2^0, X3^0, X5^0, X6^0, X7^0)$ and $U(X1^0, X2^*, X3^0, X5^0, X6^0, X7^0)$?"

Xi^*: most preferred value of Xi.
Xi^0: least preferred value of Xi.

Take the less preferred alternative and let him compare with $U(X1^0, X2^0, X3^*, X5^0, X6^0, X7^0)$. Keep asking him until the sequence of the preferences is derived. For the case in the paper, the following sequence has been derived by the subject.

$$k_6 > k_3 = k_7 > k_5 > k_1 > k_2$$

II. Finding cardinal values of k_i's

To get the cardinal values of k_i's, choose the last two k_i's from the above sequence (k_1 and k_2) and ask him the following question. "If you are asked to compare the situation $(X1^0, X2^*, X3^0, X5^0, X6^0, X7^0)$ and $(\overline{X1}, X2^0, X3^0, X5^0, X6^0, X7^0)$ which would you prefer?"

$\overline{Xi}$: Some value of Xi between the two extreme points Xi^0 and Xi^*.

If the former is preferred, raise the value of $\overline{X1}$ and ask him the same question. If the latter is preferred, decrease the value of $\overline{X1}$ and do the same. Continue until you get $\widehat{X1}$ where $(X1^0, X2^*, X3^0, X5^0, X6^0, X7^0)$ $(\widehat{X1}, X2^0, X3^0, X5^0, X6^0, X7^0)$

$\widehat{X1}$: The value of $X1$ which makes the subject indifferent between the two alternatives.

The subject derived the following value from the case.
(₩60.2 billion, $0, Useless, 1, ₩6,407 million, Minimal)

$\sim$ (₩45 billion, \$19.4 million, Useless, 1, ₩6,407 million, Minimal)

The utilities can be calculated from the above function.

$$k_1(0)+k_2(1)+k_3(0)+k_5(0)+k_6(0)+k_7(0)$$
$$=k_1(.30)+k_2(0)+k_3(0)+k_5(0)+k_6(0)+k_7(0)$$

Thus,

$$k_2=.30k_1 \cdots\cdots\cdots \text{i.}$$

The indifferent curve method was applied above since both $X1$ and $X2$ have continuous scales.

Next evaluate $X5$. Since $X5$ has a discrete scale, you have to rely on the lottery method. This method is already explained in Appendix B. Using the method, the subject derived the following equation:

$$k_5=p=.15 \cdots\cdots\cdots \text{ii.}$$

Use either one of these two techniques for the remaining Xi's. Now the subject has evaluated all the Xi's as:

i. $k_2=.3k_1$: using the indifference curve method
ii. $k_5=.15$: using the lottery method
iii. $k_5=.75k_7$: using the indifference curve method
iv. $k_3=k_7$: from the sequence of preference
v. $k_7=.6k_6$: using the indifference curve method
vi. $k_1+k_2+k_3+k_5+k_6+k_7=1$: by definition

These six variables can be identified with the above six equations.

BIBLIOGRAPHY

Friedlaender, Ann F., *The Dilemma of Freight Transport Regulation*, Washington, D.C.: The Brookings Institution, 1969.

Johnsen, Erik, *Studies in Multiobjective Decision Models*, Studentlitteratur, Lund 1968.

Jorgenson, D.W., and J.J. McCall, and R. Radner, *Optimal Replacement Policy*, Chicago: Rand McNally & Company, 1967.

Keeney, R., and H. Raiffa, *Decision Analysis with Multiple Objectives*, unpublished draft, March 1974.

Kraft, Gerald, John R. Meyer, and Jean-Paul Valette, *The role of Transportation in*

Regional Economic Development, Lexington, Massachusetts: Lexington Books, 1971.
Levitt, Theodore, *Industrial Purchasing Behavior*, Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1965.
Meyer, John R., Merton J. Peck, John Stenason, and Charles Zwick, *The Economics of Competition in the Transportation Industries*, Cambridge, Massachusetts: Harvard University Press, 1964.
Mutsaers, Anthony, "Roads v. Rails in Developing Nations—A New Look," *Transportation Journal*, Vol. 8:56-60, Winter, 1968.
Newcomb, Robinson, and Ralph E. Rachel, "Road vs. Rail in Developing Countries," *Transportation Journal*, Vol. 3:4, Summer, 1964.
Prest, A.R., *Transport Economics in Developing Countries*, New York: Frederick A. Praeger, Publishers, 1969.
Raiffa, Howard, *Decision Analysis*, Reading, Massachusetts: Addison-Wesley, 1970
Scaperlanda, A., "Role of Transportation in the Economic Integration of Underdeveloped Areas," *Journal of Land Economics*, 42:205-9, 1966.
Chang, Shin Kyu, *Korea Statistical Yearbook*, Vol. 20, Seoul, Korea, 1973.
The Department of Transportation, *Statistical Yearbook of Transportation*, 1974.
The Department of Transportation, *Transportation White Paper*, Seoul, Korea, 1971.
Economic Communication Company, *Transportation Annual*, Seoul, Korea, 1971.
Korean Transportation Company, *The History of Korean Transportation Company*, Seoul, Korea, 1967.
Presidential Secretariat, *Research Report for Improvement of railroad Operation and Management*, Seoul, Korea, 1968.