ISSN: 2288-2766
https://accesson.kr/eajbe
doi: http://dx.doi.org/10.20498/eajbe.2024.12.1.35

The Analysis of Railroad Operating Costs in Korean Railroad Projects*

SungWook KANG[1], DongHee KIM[2], GyuBae KIM[3]

Received: February 20, 2024. Revised: March 13, 2024. Accepted: March 20, 2024.

Abstract

Purpose: A railroad project is a complex system with large construction costs in the initial stage and ongoing operating costs over its lifecycle. Current railroad projects tend to be based on construction options, which leads to huge deficiencies in operating costs. This phenomenon results from a lack of appropriate tools to accurately estimate a railroad project's lifecycle costs. This study attempts to analyze the major components of railroad operating costs and to propose a decision-making system for analyzing the long-term lifecycle costs of railroad projects. **Research design, data and methodology:** We review the literature and analyze the current status of railroad operating costs in Korea and overseas. Based on previous projects, a framework for project options and operating costs is proposed. The framework is applied to actual railroad projects to demonstrate the validity of the model. **Results:** Case analysis shows that our framework is comprehensive in analyzing the primary aspects of railroad operating costs and plays an effective role in choosing various railroad project options. This study points out that the railway project operates inefficiently because estimating long-term costs without reflecting specific project options causes many errors. **Conclusions:** A major contribution of this study is the development of an improved framework for accurately estimating operating costs and providing policymakers and engineering firms with a holistic decision support system. Detailed components in estimating operating costs of the railroad business are discussed. And we present a decision-making tool that policymakers and private businesses can use in planning the railroad business.

Keywords : Railroad project, Cost estimation, Operating costs, Scenario options, Decision support system

JEL Classification Code : H43, L92, M48, R42

1. Introduction

The A railway project is a long-term project that involves many factors in its construction and operation and requires a large budget. Accordingly, the government conducts railway projects by establishing a route plan, evaluating the feasibility of planning, and establishing a transportation-related plan. In the planning stage, the estimated project construction and operating costs are calculated mainly based on the preliminary feasibility study standard guidelines, which regulate the estimation method used for each railroad system type (Lee et al., 2021).

As the useful life of rail routes is a minimum of 30–50 years, continuous operating costs, in addition to the initial construction costs, account for a large proportion of the project cost. Therefore, it is desirable to analyze the construction and operation costs of railway projects from the perspective of their entire life cycle and compare them with

* This study was supported by a research grant from R&D program (PK2402C4) of the Korea Railroad Research Institute.
1 First Author. Senior Researcher, Korea Railroad Research Institute, Korea, E-mail: kangsw@krri.re.kr
2 Second Author. Principal Researcher, Korea Railroad Research Institute, Korea, E-mail: kdh777@krri.re.kr
3 Corresponding Author. Professor, Daejeon University, Korea, E-mail: gbkim@dju.ac.kr

the benefits derived from them (Flyvbjerg et al., 2002; Kang et al, 2021; Kang et al., 2019).

However, domestic railway project-related standards currently deal with construction costs in detail up to design standards, but only provide rough estimates of the operating costs. Maintenance and alternative investment costs, in particular, are outlined in a declarative manner, such as by applying the unit of won per kilometer, despite being a large proportion of the total operating cost (Kim et al., 2019).

Of course, the guidelines recommend that the appropriate maintenance cost be calculated and applied according to the system selected because maintenance costs vary greatly from system to system; however, in the initial planning stage, the system is yet to be designed in detail, and therefore most of the estimates are made for time and cost reasons (Lee et al. ,2021).

However, these rough estimates may differ significantly from the actual operating costs; some studies have found actual operating costs to be 1.5 times those estimated based on the preliminary guidelines for basic planning. In proposed private projects, the difference between the actual and estimated operating costs is reduced by estimating the cost over the entire operating period through subdividing maintenance and alternative investment costs into several areas (Kim et al., 2019; Kang et al., 2019). The main cause of this problem can be said to be the absence of a decision support system that can flexibly compare and analyze detailed project execution options in the early stages.

This study proposes an operating cost structure that can be used to analyze the long-term lifecycle of railway lines by analyzing the main factors constituting their operating costs. First, a detailed theoretical analysis of the components that constitute the operating costs of a railroad is presented. On the basis of that analysis, this paper presents a framework that can increase the rigor of operating cost estimation and reduce errors.

Second, it presents a decision-making tool that policymakers and private businesses can use when planning railroads. Under budget constraints, railroad businesses need to select projects that can achieve the greatest benefits at the lowest costs. Consequently, this study aims to support policymakers in selecting rational and public-interest railway projects by proposing decision-making tools for appropriate cost estimation. Additionally, it can be used by private businesses to identify cost effective railroad projects.

Distinctive features of this study are two folds. First, we consider not only construction costs but also operating costs in order to evaluate the total costs over the project lifecycle. Ignoring operating costs at the initial stage may result in significant estimation errors because a railroad project is a very long-lasting project and an infrastructure is very costly to modify. Second, our framework is tested using actual data. One concern in railroad study is that it is difficult to get cost data because the company consider them as corporate secrets. Using the data from long-run research projects (Kim et al., 2019), we apply our framework into actual data and check the validity of our model.

The remainder of this paper is organized as follows: First, it analyzes the current status of railroad operating costs in Korea and overseas. Subsequently, the project promotion options necessary to estimate the operating costs of a railway project and the main factors that can support it are analyzed. Finally, by analyzing the case of an actual railroad project using the proposed framework, we illustrate the extent to which the model can reduce prediction error.

2. Literature Review

2.1. Estimation of Operating Expenses for Domestic Railway Projects

Operating costs in railroad projects have not been studied well in Korean railroad project management. Most studies tend to focus on construction costs or demands derived from railroad system (Lee & Park, 2021). One of few exceptions is Lee et al. (2021) examining money assessment on urban rail projects. While this study proposes decent risk-based evaluation model, components of operating costs have remained in a traditional approach.

Domestic railway investment costs are calculated in accordance with the detailed guidelines for conducting preliminary feasibility studies of the KDI (Lee et al., 2021). Operational costs, however, are subject to different standards depending on the type of project, of which there are four kinds: high-speed rail, general rail, wide-area and urban rail, and light rail. The detailed components of the operating costs consist of labor costs, power and power costs, maintenance costs, actual operational costs of general management, and the alternative investment costs of vehicles and railway facilities. Figure 1 illustrates the structure of major components.

The operating costs of the domestic railway projects are as follows: Each data point describes the estimates obtained in the preliminary feasibility study. As the estimated year of each data point and the characteristics of each route were different, it was difficult to make a rigorous comparison. In the case of a simple average of the data at table 1, it appears that the construction cost is approximately 43.7 billion won per kilometer of construction extension, and the annual operating cost is approximately 91.4 billion won.

Table 1: Cost estimations on recent railway lines in Korea

Line	Estimation year	Length (km)	Construc-tion cost	Operating cost
Suseo-Pyeongtaek	2009	60.9	39,519	1,042

Susaek-Gwangmyung	2022	23.6	24,399	304
South-Inland	2017	179.7	44,294	707
Walgok-Pangyo	2015	38.4	23,178	592
Suseo-Gwangju	2023	19.4	9,399	299
Total (5 cases)		54,986	43,467	11,519

Note: KRRI internal report using pre-feasibility studies

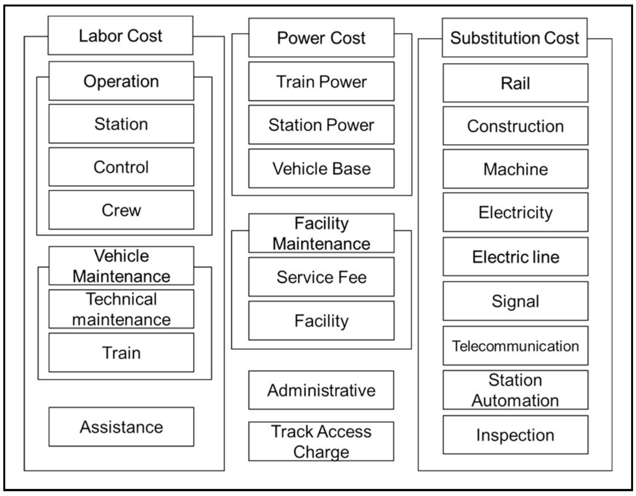

Figure 1: Components in estimating operating costs in railroad projects (modified from Kim et al. (2019))

2.1. Estimation of Operating Costs for Overseas Railway Projects

In the case of railway projects, it is not easy to perform comparisons between countries, because different standards are applied in each country. International organizations present the data related to the construction and operation of railway projects and they appear in table 2.

Table3 shows that the operating costs of high-speed trains are relatively constant across countries. The cost of running trains in France is slightly lower than those in Germany and Italy. Italy spends considerably less time on Track Maintenance than other countries. This may be a result of private-sector competition. Spain appears to have significantly higher signaling costs as a percentage of the total than other countries. France and Italy did not report telecommunications and other costs, which are estimated to be low in these countries.

Table 2: Major highspeed railroad lines over the world

Nation	Highspeed Line	Open year	Construc-tion cost (billion ₩)	length (km)	Cost /km (million ₩)
Japan	Tokyo-Osaka	1964	1,007	569.71	1,768
	Osaka-Kakata	1972	3,230	624.43	5,172
	Tokyo-Aomori	1982	12,066	539.13	22,381
	Omiya-Nagata	1982	7,325	336.35	21,778
France	Paris-Lyon	1981	2,255	1,002.62	2,249
	Paris-Tours	1990	1,883	725.81	2,594
	Balencia-Marseille	2001	4,434	799.84	5,544
	Paris-Baudrecourt	2007	4,785	1,079.87	4,431
Germany	Hannover-Wurzberg	1991	8,267	326.70	25,304
	Manheim-Stuttgart	1991	2,507	99.78	25,130
Spain	Madrid-Vallodolid	2007	6,909	180.25	38,331
	Cordoba-Malaga	2007	4,171	154.5	27,002
	Madrid-Barcelona	2008	11,628	621.21	18,719
Italy	Torino-Milano	2009	12,789	125.53	101,882
	Milano-Bologna	2008	11,749	185.07	63,484
	Bologna-Firenze	2009	9,657	78.86	122,465
	Roma-Napoli	2009	9,285	207.61	44,724
China	Beijing-Shanghai	2011	39,199	1,432.32	27,368
	Shanghai-Hangzhou	2010	5,201	149.67	34,750
	Wuhan-Gwangzhou	2010	20,694	967.22	21,396
	Haikou-Sanya	2010	3,580	307.38	11,648

Note: Modified from Feigenbaum (2013). The money value (Korean won) was calculated using the foreign currency rate in 2013.

3. Operating Cost Structure for the Analysis of Railway Projects

3.1. Direction of Decision-Making Structure Considering the Life Cycle of Railway Projects

The step-by-step business procedure of an existing railway transportation project can be divided into planning and implementation stages. The business procedure proceeds in the following stages: policy establishment → transportation plan → construction → operation. However, these stages are not considered in an integrated manner due to the disconnection of requirements between steps.

For example, there is no analysis or review to determine whether policy-making goals (e.g., access time and expression speed) set in the legal basic plan, such as the national infrastructure plan and national railway network plan, are met at the transportation plan, construction, and operation stages; if not, the reason for the failure; the extent of the failure; finally, how to set up cost and business promotion options to meet them.

Table 3: Estimation of operating costs in various countries

	Belgium		France		Italy		Spain	
	Cost per km (₩)	Ratio	Cost per km (₩)	ratio	Cost per km (₩)	ratio	Cost per km (₩)	ratio
km of track	141.62		2,637.71		492.46		949.51	
Track Maintenance	224,011,898	43.7%	16,631,841	12.60%	27,648,847	16.52%	32,663,089	40.4%
Electrification	41,697,310	8.1%	3,658,465	2.77%	11,426,410	6.83%	7,208,620	8.9%
Signaling	52,568,147	10.3%	4,406,099	3.34%	21,047,366	12.57%	20,890,123	25.9%
Telecommunications	19,375,752	3.8%	16,491,725	12.50%	16,491,725	9.85%	13,607,699	16.8%
Other Costs	175,139,528	34.2%	90,768,150	68.79%	90,768,150	54.23%	6,396,771	7.9%

Note: Modified from Kim et al. (2019). The money value (Korean won) was calculated using the foreign currency rate in 2013.

In addition, there are cases in which construction options cannot be promoted because of their limitations, even if there is a need to increase the number of organizations or shorten the time trial during the opening operation stage. In fact, these problems have been known for a long time but have not been resolved in the disconnected approach of the existing step-by-step procedures.

To solve this problem, it is desirable to establish a plan that considers the requirements that can materialize in the future in the project's planning stage, and accordingly, identifies business promotion options in advance (Flyvbjerg et al., 2002).

Therefore, stakeholder requirements should be reflected at each stage of the work. Moreover, various business promotion scenarios can be identified by considering alternative options for the key factors that affect overall cost in the fields of policy, operations, and construction.

However, in railway projects, it is necessary to focus on the operating costs. Currently, construction costs are dealt with in detail by design standards in Korea, but operating costs are only roughly estimated.

For instance, maintenance and alternative investment costs are only specified in outline, such as applying won units per kilometer, despite them constituting a high proportion of total operating costs. The guidelines also recommend that appropriate maintenance costs be calculated and applied according to the system selected because maintenance costs vary greatly from system to system; however, at the initial planning stage, the system is yet to be designed in detail, thus most of the estimates are made for time and cost reasons (Lee et al., 2021; Kim & Kang, 2021).

However, in the case of proposed private projects, maintenance and alternative investment costs are subdivided into 9–11 areas in the same environment before the design of construction and systems, which differs from the calculation method of outlining operating costs.

For example, even for the same route extension project, operating costs vary significantly if the number of stops is different. In the case of a recent heavy rail project, it was confirmed that there was a more than 1.5 times difference between the actual operating costs calculated using the private business analysis method and those estimated based on the preliminary guidelines for the basic plan of the project (Kim et al., 2019); moreover, the operating cost estimate in the basic plan was so low that it could not be used as a starting point for operational negotiations.

Therefore, it is desirable to apply a detailed operating cost method in estimating operating costs (Kim & Kang, 2021). Consequently, this study intends to apply the proposed operating cost calculation method to the private sector.

3.2. Business Promotion Options and Cost Structure of Railway Projects

This study reviews the results and processes of studies related to the cost estimation of railway projects conducted by government-funded research institutes. At first, we set the key factors and promotion options that affect costs at each stage of the fields planning → construction → operation.

By doing so, it is possible to estimate LCC by setting minimum project promotion options. If a policy or operational field option is set or changed among these project promotion options, the LCC construction and operational costs that are affected should be revised and estimated.

These factors are not considered in the analysis system based on the existing guidelines, resulting in the need to reanalyze the entire structure of construction or operations even for partial changes in options.

For example, if the number of organizations is revised to alter the organizational capacity, which is an option related to transportation capacity in the operation field, the number of organizations per organization and the size of the stations will be affected. This affects the station construction costs, initial vehicle purchase costs, vehicle-based construction costs, labor costs, power costs, and maintenance costs.

Regarding policy matters, key factors include target transport power, project type, implementation entity, route size, route type, and service level. The key factors in operations include the operation period, transport capacity, operation method, operation method, control type, manpower operation, and power contracts. System size is a key factor in construction.

Each key factor has detailed implementation options for promoting the project. For example, in the case of route type, whether to establish or extend a new route, likewise the presence or absence of a vehicle base, has a great influence on the overall project and maintenance costs from a lifecycle perspective. However, in the current situation in Korea, these options are not reflected in the initial planning stage because of the lack of a detailed design. Similarly, in terms of the driving method, it is desirable to consider the choice among unmanned, manned automatic, and manual, as it greatly affects the number of drivers and labor costs in the future. However, this is likewise not reflected at present.

Finally, the following operating facility cost structure can be used depending on the project promotion option in a scenario setting: The operating costs are largely composed of labor, power, maintenance, general management, track usage fees, and alternative investment costs. Labor costs are largely composed of sales and operations, maintenance, and business support. The power cost is primarily composed of vehicle power, station power, and vehicle base power costs. Maintenance costs are largely composed of service payments and facility maintenance costs. Alternative investment costs should be incurred in all fields related to the long-term operation of the railroad, such as trajectory, construction, machinery, electricity, tram lines, signals, communication, service automation, and inspection. Table 4 summarizes major options for building scenarios.

Table 4: Railroad Project Options for building up scenarios

Area	Major Factors	Railroad project options
Policy	carrying capacity	Demand
	project type	highspeed rail, traditional rail, urban rail, light rail
	project entity	government, local-government, private enterprise
	line size	length, number of stations, transit station
	line type	one track, double track, double track subway
	line shape	new line, extended line, railway vehicle base
	service level	crowdedness, operating speed, operating hour, express line
Operation	operating period	30yr, 40yr, 50yr
	operating capacity	utilization ratio, operational headway, organized capacity
	operating type	isolated, transit, direct link
	driving type	autonomous, autonomous with driver, manual
	control type	dependent, affiliated
	manpower management	outsourcing tasks, employee salary level
	utility contract	electricity discount rate
Construction	system size	amount from system components

Note: Modified from Kim et al. (2019)

3.3. Decision Support System for Railway Projects

The decision-making model consisted of selecting requirements, promotion options for scenario setting, construction and operating project costs, and the costs for each scenario.

Requirements refer to factors that are responsive to problems expected to occur in the operational stage in addition to the analysis items reflected in the investment evaluation guidelines used at the planning stage.

Regarding project promotion options, scenarios were organized for the promotion of the railway transportation projects, and options for each scenario's policy, operation, and construction fields were set.

The analysis of construction and operating costs was conducted from the LCC perspective as part of the cost estimation process of new projects, such as a new railway transportation project or an extended route. Cost analysis was performed by combining the preliminary and outline cost calculations of the feasibility study based on the standard guidelines with the detailed cost calculation methods used by the private sector.

Cost analysis and requirement comparison for each scenario were used for verification and to determine applications in the field and availability using the constructed decision support system. Evaluation indicators that reflect cost and requirement satisfaction can be used as analytical methodologies. The scenario with the highest score that satisfies the requirements is optimally defined, rather than the project promotion option with the lowest LCC.

$$V = P/C$$

P = P Score (performance point)

C= Life Cycle Cost

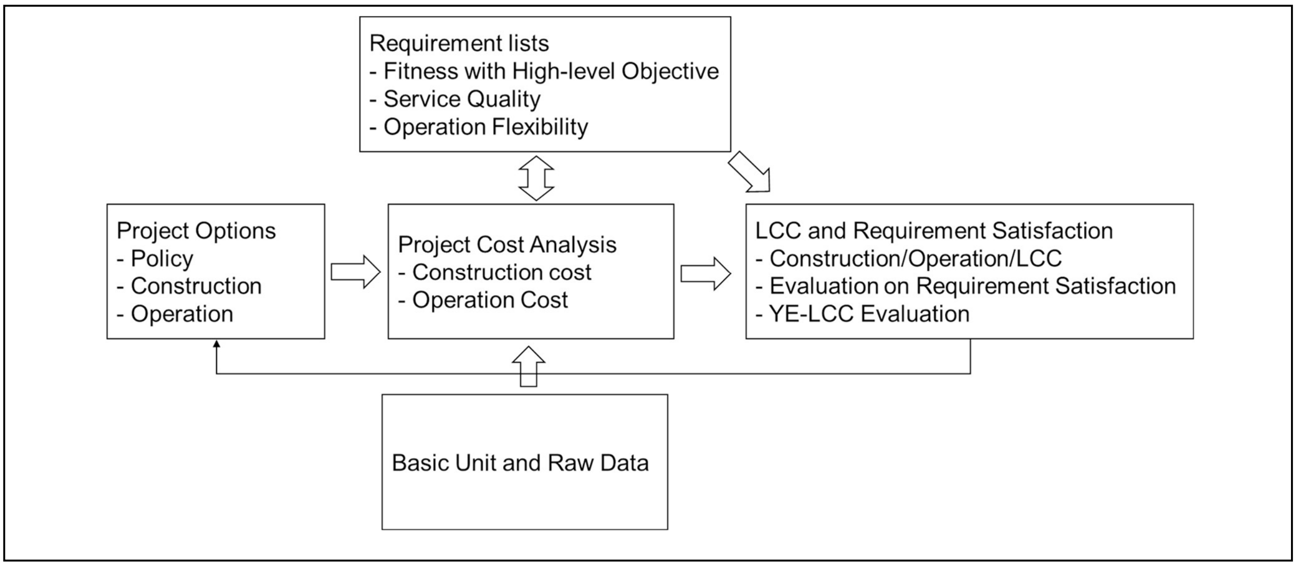

Figure 2: An comprehensive overview of estimating railway project costs (modified from Kim et al. (2019))

Through this approach, we intend to implement a decision support system for optimal route selection by selecting various options and deriving the corresponding results. Figure 2 illustrate the overall structure of the system.

4. Case Analysis: Railroad Projects

The results of testing this decision-making model using domestic heavy and light rail cases (Kim et al., 2019) are as follows.

First, the following seven application requirements were determined as follows. They were selected and applied to the requirements pool through interviews and expert advice. Based on these interviews, the transportation order per peak time was set at 12,000 people/h or more; the construction cost, at less than KRW 120,000 billion; the operation trial at peak time, at less than 5 min; the non-peak time, at less than 10 min; the interstation distance, at less than 4 km; the average re-vehicle congestion at peak time, at less than 150%; and the facial expression time, at less than 40 min.

The budget in the selected cases was too large to reflect all requirements. A decision support system is required to examine the budget required for a combination of various requirements, and this study aims to fulfill such a role. Table 5 shows the example to assign weights.

Each requirement had a weight of 0.1; however, the peak driving time had a weight of 0.3, while the peak average congestion had a weight of 0.2, indicating that policymakers had a higher weighting for these two requirements.

The project promotion options for each scenario of the four major scenarios were as follows: each scenario was differentiated in terms of factors such as transfer station, route type, facial expression speed, service level, transport capacity, operation method, vehicle base construction, driving method, management type, manpower operation, and station staff consignment.

Table 5: Requirement to satisfy operating scenarios

Number	Requirement	Weight
Requirement 1	Carrying capacity at peak time is over 12,000 man/hour.	0.1
Requirement 2	Construction cost is less than 120,000 billion won.	0.1
Requirement 3	Operating headway at peak time is within the 5 minutes.	0.3
Requirement 4	Operating headway at non-peak time is within the 10 minutes.	0.1
Requirement 5	Distance between station is farther than 4 km.	0.1
Requirement 6	Average congestion ratio at peak time is lower than 150%.	0.2
Requirement 7	Average operating time is less than 40 minutes.	0.1

Urban and light rail were suggested as the primary options for project type. These two choices were considered because they have a significant construction and maintenance costs.

In the case of route size, whether a transfer station is installed has a significant influence on construction and maintenance costs. But this is not reflected in the initial preliminary feasibility study because the route has not been confirmed. However, there is a good argument that this is a factor that needs to be reflected in the planning stage of the project.

Regarding the service level, the introduction of express routes greatly affects customer service and traffic time. Therefore, it is necessary to consider and incorporate these factors in advance.

Vehicle-based construction also has a significant impact on future maintenance costs, which must likewise be appropriately considered in the preliminary project planning stage.

Station crew members have a significant impact on operations depending on whether they are directly hired or entrusted; however, there is currently no way to consider this option in advance.

A decision-making process that considers this option as well as the others mentioned in this paragraph is required, as the one proposed in the present study.

Table 6: Scenario setup options for heavy subway

Key Factor	Scenario Setup Option			
	Current Case	Scenario 1	Scenario 2	Scenario 3
project type	urban rail	urban rail	urban rail	light rail
project entity	local government	local government	local government	local government
line size	8.025km 6 stations 0 transit	8.025km 6 stations 1 transit	8.025km 6 stations 0 transit	8.025km 6 stations 1 transit
line shape	extended line	new line	extended line	new line
service level	peak time 4 non-peak time 15 crowded ratio 150% no express	peak time 4 non-peak time 15 crowded ratio 150% no express	peak time 4 non-peak time 15 crowded ratio 150% no express	peak time 4 non-peak time 15 crowded ratio 150%
operating period	30 yr	30 yr	30 yr	30 yr
operating capacity	10/24 minute 8 cars	6/10 minute 6 cars	8/15 minute 8 cars	2.5/5 minute 3 cars
operating type	direct link	transit	direct link	transit
railway vehicle base construction	no	construct underground heavy maintenance	no	construct underground heavy maintenance
driving type	manual	manual	manual	autonomous
control type	affiliated	no	affiliated	independent
work rotation	3 group 2 shifts	3 group 2 shifts	3 group 2 shifts	Daily working/ 3 group 2 shifts
utility contract	50%	50%	50%	50%
outsourcing heavy maintenance	outsourcing	outsourcing	outsourcing	outsourcing
outsourcing light maintenance	outsourcing	outsourcing	outsourcing	outsourcing
outsourcing station employee	hired	outsourcing	hired	outsourcing

Note: Modified from Kim et al. (2019)

The outcomes of the calculation and comparison of the LCC costs and requirement satisfaction for each scenario were as follows: Sixty points were calculated for Scenario 1, 50 for Scenario 2, and 60 for Scenario 3. The V value according to the change in the project promotion option shows an improvement rate of more than 20% compared with the reference case. In Scenario 2, there was no significant improvement in the satisfaction of requirements compared to the reference case, but the V improvement rate improved by more than 20%, improving by 123%.

The improvement rate compared to the other scenarios was insignificant. The P score, which quantifies the requirement satisfaction of Scenarios 1 and 3, was the same as Scenario 1 at 60 points, but the V improvement rate was significantly higher because of the influence of LCC. The optimal improvement scenario that satisfied requirements and had the minimum LCC was identified as Scenario 3.

Table 7: Outcome from Scenario Analysis

	Current case		Scenario 1		Scenario 2		Scenario 3	
construction cost	9813		10094		9941		10257	
operating cost	7468		6690		7646		5283	
annual operating cost	249		223		255		176	
LCC	17,281		16784		17587		15540	
Requirement 1	x	0	0	10	0	10	x	0
Requirement 2	x	0	0	10	0	10	x	0
Requirement 3	0	10	x	0	X	0	0	30
Requirement 4	0	10	0	10	X	0	0	10
Requirement 5	x	0	x	0	X	0	x	0
Requirement 6	0	20	0	20	0	20	0	20
Requirement 7	x	0	0	10	0	10	x	0
Sum of P	40		60		50		60	

Note: Modified from Kim et al. (2019)

5. Conclusion

This paper presents a decision-making model for accurately estimating the costs of railroad projects. First, domestic railroad projects were analyzed according to the method used to estimate operating costs. Subsequently, a decision-making model for the establishment of an appropriate plan for a railroad project was presented, and the model was tested on actual cases.

This study highlights that railway projects currently operate inefficiently because estimation errors due to the method of estimating long-term costs with rough estimates without reflecting specific business promotion options. In response, it proposes an alternative model that considers the business promotion options of railways and the resulting cost changes.

Thus, various conclusions can be drawn. First, government policy managers can conduct a clear evaluation of new the existing railroad systems; thus, investment costs can be expected to be reduced. Therefore, it is possible to prevent duplication and overinvestment, and secure the performance level of the railroad system in the government, and railroad industry. In addition, the Ministry of Strategy and Finance and Ministry of Land, Infrastructure, and Transport can use this model to improve the systems and guidelines for the promotion of railroad transportation projects.

A theoretical contribution of this study is to fill the gap in the literature by presenting a holistic framework on railroad projects. In planning a long-run project such as a railroad, it is necessary to have a simultaneous consideration on short-term construction costs and long-term operating costs. Given that current domestic studies are mainly concerned with construction costs and demand forecasting, our study integrates major components in railroad planning and opens a new avenue for building a realistic decision support system.

From the standpoint of railroad engineering companies, it is possible to expand their participation in the railroad business by minimizing risks, which is a major problem that arises when the private sector participates in the railroad business.

This study has the following limitations that should be addressed in future research. First, it is necessary to expand the scope of the model by analyzing various types of railroad businesses, such as high-speed rail. In this study, the requirements and business promotion options were analyzed based only on data from lightweight and urban railways. Because the characteristics of high-speed rail and urban rail are quite different, it is necessary to develop a more comprehensive model that can reflect this.

Second, it is necessary to develop a model that reflects the time value and risks in the railroad business. Because the railroad business is long-term, many inflation and currency value changes occur as the project progresses and during operation. This is likely to modify the initial estimates significantly. Therefore, uncertainties such as these that arise during construction and operation lead to numerous errors. Because these uncertainties and risks are inevitable in the railroad business, it is necessary to find a way to properly reflect them in advance rather than underestimating them and having to adjust for them in the future.

References

Feigenbaum, B. (2013). High speed rail in europe and asia: Lessons for the United States. *Policy Study, 418*(May 2013), Reason Foundation.

Flyvbjerg, B. Holm, M., & Buhl, S.L (2002). Underestimating costs in public works projects: Error or lie. *Journal of American Planning Association, 68*(3), 279–295.

Kang, S. W., Kim, D. H., & Kim, K. T. (2019). Cost overrun and underestimation in the construction of railway infrastructure: Causes & implications. *Journal of The Korean Society for Railway, 22*(11), 905-912.

Kang, S. W., Kim, D. H., Yu, J. K., Lee, K. C., & Moon, D. S. (2021). Benefits of early stakeholder involvement in korean railway infrastructure project. *The Journals of Economics, Marketing & Management, 9*(5), 15 – 25.

Kang, S. W., Oh, S. M., & Kim, G. B. (2022). The effect of the introduction of the express highspeed railway in Korea. *East Asian Journal of Business Economics, 10*(4), 47-54.

Kim, D. H. et al. (2019). *Development of technology to analysis the optimal requirements and financial investment for railway public transportation system*. Research Paper. Korea Railroad Research Institute.

Kim, G. B., & Kang, S. W. (2021). A study on the customer-based pricing approach for railway fare of express trains. *East Asian Journal of Business Economics, 9*(4), 93 – 102.

Lee, H. S., Yoo, J. K., Kim, D. H., Lee, K. C., Kang, S. W., & Moon, D. S. (2021). Study on risk based value for money assessment on urban rail project. *Journal of Korean Society for Urban Railway, 9*(4), 1117-1129.

Lee, J. H. & Park, M. C. (2021). Estimating induced demand with opening of railway projects. *Journal of the Korean Society for Railway, 24*(5), 478-489.

Lee, W. H. et al. (2021). *Guidelines for pre-feasibility test: Road and rail*. Research Paper. Korea Development Institute.