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Comprehensive Safety Index for Road Safety Management System

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Abstract: A safety-index-based road safety management system (RSMS) is a tool to help identify locations where safety intervention is needed. To date, various safety indices have been developed and utilized, but it is rare to consider the plan–do–check–act structure in an RSMS when studying the decision-making methodology. In this study, 36 indicators and a system of evaluation indicators were selected based on the major classifications of performance, effect, and improvement. Performance was categorized by safety system components and effect was reflected in the safety status, such as the number of injuries. The indicators were validated, and a classification methodology for safety groups was proposed through cluster analysis. It was found that there was no correlation between the indicators and the population, budget, or road area by administrative district. It was also found that no particular indicators had a significant impact on the overall result in the major category or the overall index. It was determined that the developed indicators were suitable for administrative district-specific safety monitoring. It is expected that these indicators will be continuously utilized and enhanced in the national evaluation of road traffic safety.

Keywords: safety index; road safety; safety group; safety assessment

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1. Introduction

Sustainability and traffic safety are inseparable and interrelated since they both concepts are related to improving living environments. Sustainable traffic safety implies that the traffic environment is designed to minimize traffic accidents and mitigate the severity of the accidents. The fundamental principle of sustainable traffic safety is that a road traffic system cannot be sustainable if it is not safe for people. Traffic safety is now acknowledged worldwide, and the international standard for road traffic-safety-management systems, ISO 39001 [1], takes into account all organizations that use, design, and build roads and vehicles and incorporates safety-related performance factors. Furthermore, aligning with the global movement towards incorporating international standardization of road traffic safety systems in Korea, this study specifically concentrated on synthesizing factors related to safety performance. There are safety indicators for the government to maintain road traffic safety [2–4], but the data are limited on indicators for local governments that take into account the plan–do–check–act (PDCA) model presented in ISO 39001. The model, known as the Deming cycle or plan–do–study–act (PDSA), serves as a fundamental management system extensively employed in both management and work contexts. It endeavors to enhance management within the quality-management domain through an iterative four-step approach, fostering continuous improvement of services and problem resolution. This paper describes the development of a comprehensive safety index for local government road safety management systems (RSMSs). In the context of local governments, Korean standards have been applied with necessary modifications, and non-Seoul local governments engage in ongoing exchanges and research. This underscores the importance of categorization to enable the implementation of policies customized to the distinctive characteristics of each administrative district. Korean data were utilized to obtain indicators that local governments can use for safety management by reflecting the PDCA model. The data can also be used to make academic contributions to road traffic-safety-management systems.

Road safety management systems (RSMSs) have been developed by various organizations including the Organization for Economic Cooperation and Development (OECD), the World Bank, and the European Union (EU) [5–7]. The safety-system approach has been widely applied in the industrial sector. Traffic accidents are now increasingly perceived, by both individuals and the public, as being a shared responsibility. This is due to the public's role in establishing safety standards and managing vehicles and roads. Consequently, it is imperative to assess whether individuals and the public are making suitable efforts for traffic safety. This implies that safety is regarded as a product and a service. This RSMS model complies with New Zealand's target-setting framework (Land Transport Safety Authority, 2000) [8] and the World Bank guidelines for developing prototype safety management capacity evaluation indicators.

In the United States, the state government establishes road-safety policies, is responsible for safety management such as regulations, and implements post-improvement measures in a continuous manner [9–11]. In recent years, there have been many cases of utilizing road traffic-safety-management systems as suggested in ISO 39001 [12–14]. To implement road traffic-safety-management systems, it is necessary to establish a performance index that considers the government's perspective on road traffic safety and the system-management perspective [15]. Although numerous safety indicators have been developed, no indicator that simultaneously reflects the two perspectives has yet been identified.

When it comes to road traffic-safety-management systems, planning, monitoring, and feedback are crucial [16–18]. From the government's perspective, continuous management of the established plan is required, and systematic management of the national plan at the provincial level is essential [19–22]. To this end, indicators (for example, pedestrian crossing stop line compliance rate, rate of turn signal illumination, traffic signal compliance rate, seatbelt use rate, helmet use rate of two-wheeled vehicle users, use of mobile devices while driving, driving under the influence, speed-limit violations, pedestrian crossing traffic signal compliance rate, rate of pedestrians using mobile devices while crossing street, and jaywalking) are necessary to evaluate the efficacy and consistency of objectives presented in national and local plans [23]. In Korea, for instance, when a national road safety master plan is established, local government develops their own plans which are evaluated accordingly. In this paper a comprehensive safety index for local government road safety management systems (RSMSs) is developed.

In Section 2, existing research on road safety indicators in terms of RSMSs is reviewed. Section 3 details, in stages, the indicator development methodology. The outcomes of the analysis are presented in Section 4, while discussions and conclusions are summarized in Section 5.

2. Literature Review

Until recently, road safety indicators had been the subject of ongoing research. Illustratively, in the instance of the OECD's Towards Zero mentioned earlier, elements outlined in the Ambitious Road Safety Targets, encompassing traffic systems, road safety, vehicle safety, membership, and countermeasures, were incorporated. This resulted in the formulation of a comprehensive indicator capable of systematic evaluation, utilizing both individual and macro indicators. This contribution aimed to enhance academic understanding and contribute to the advancement of safety indices. Riccardi et al. (2022) developed a safety index to contribute to the development of safety evaluation procedures for the entire road network, and attempted to prioritize the safety issues that had the greatest influence on collision reduction, and conducted the study with a focus on a particular region. In their study, the calculation procedure for the safety index was validated in 50 samples from Rome, Italy, and the correlation between the safety-index score and the collision estimate, by lane type, was demonstrated [24]. Demasi, F. et al. (2018) proposed an analysis methodology for estimating road traffic safety in detailed road networks within a city and attempted to identify and index the causal factors between driving-safety-related defects and traffic collisions to assess the fatality or injury rate. A risk index for each section constituting the road, such as traffic volume, average speed, and prediction of vulnerable roads, can be indicated in the event of a traffic collision. Demasi, F., et al. (2018) attempted to highlight the design of road traffic safety in the city and the use of risk management [25]. Chen, F., et al. (2016) developed a road safety performance indicator (SPI) to derive a universally accepted approach for road traffic safety enhancement, and combined it into a comprehensive indicator, to establish a systematic safety-index methodology through key activities to verify outstanding road traffic safety [26]. Papadimitriou E. and Yannis G. (2013) implemented SPIs for RSMS utilizing data from 30 European nations as a theoretical framework [27].

The development and utilization of safety-related indicators by domestic and international organizations are currently underway. In the case of the EU, a number of indicators characterizing road traffic safety outcomes and road-safety-policy performance were aggregated into a single figure, which represented a country's overall road safety index. This includes structure and culture, safety measures and programs, SPIs, the number killed and injured, and social costs, each of which is categorized into the three target hierarchies of outcome, policy performance, and policy context (International Transport Forum (ITF), 2022) [28]. In 2018, the Statistics Research Institute of Korea established safety indicators in three categories: hazard factors (total safety, social safety, and environmental health and safety), vulnerable factors, and safety management. As one of the transportation policy evaluation indicators, the Korea Transport Institute reflected traffic collision costs (by means, by accident severity, and by traffic collision cost composition) in its 2021 report. Evaluation studies based on safety indicators have been continuously conducted both domestically and internationally. Amoros (2003) incorporated regional characteristics and road types as exposure variables based on the collision rate and collision severity distribution in certain regions of France and presented a model to predict the number of collisions and collision severity by region [29]. AL Haji (2005) developed a methodology for calculating the road safety development index by establishing six categories of exposure indicators: road traffic safety level, user safety level, vehicle safety level, road level, user behavior, and socioeconomic conditions. On this basis, the level of road traffic safety in Sweden and major Southeast Asian nations was compared [30]. The primary objective of this study was to construct a comprehensive set of exposure and risk indicators, encompassing key parameters of road safety pertaining to human–vehicle–road dynamics and national patterns. This approach moves beyond the consideration of single and isolated indicators, such as accident rates. Instead, it incorporates relevant characteristics for multiple countries, particularly developing nations. Utilizing the road safety development index (RSDI) indicators, Singapore and Brunei emerged with the most favorable RSDI records among ASEAN countries, while Laos, Cambodia, and Vietnam exhibited lower RSDI records. These promising RSDI outcomes warrant further exploration through additional applications with samples from larger countries and diverse regions worldwide.

The reviewed safety indicators had a cross-sectional structure, and there were no indicators that considered the PDCA model. In this investigation, the cross-sectional structure was delineated as a data framework wherein multiple variables were concurrently collected within the same period. Regional comparisons of road traffic safety were also conducted, but it was not possible to compare safety-related indicators comprehensively from the perspective of road traffic safety management (no indicators were considered for road safety management system (RSMS) activity or organization). Therefore, we systematically analyzed the indicators and developed an evaluation methodology for each local government.

3. Methodology

In order to employ an RSMS, we established a hierarchy and chose sub-indicators for each hierarchy. The indicators were founded on the tasks outlined in Korea's National Road Safety Master Plan. Utilizing cluster analysis, we derived specific indicators for each administrative district in Korea, which were then incorporated into an interregional evaluation system. The safety system of an RSMS categorizes the three-stage division into a pyramid shape, aiming to attain the desired level of results. Concerning performance, it is posited that enhancements in safety-related performance can occur only through concerted efforts at the institutional management and policy levels, rooted in public responsibility and operational strategies.

We conducted case studies of the operation of road traffic safety evaluation systems by overseas region, area, and local government for regional road traffic safety, and compiled 163 detailed indicators currently implemented at home and abroad. Using the collected indicators, we selected those that conformed to the safety plans announced in Korea, could be collected, and could be applied to an RSMS. During this process, we consolidated overlapping indicators and gave priority to indicators that continued to be collected. Finally, we came up with 36 indicators. The selected indicators were reconstructed in accordance with the performance, effect, and improvement hierarchy applicable to the RSMS.

We compiled and selected domestic and international evaluation indicators for road traffic safety. An RSMS considers that evaluation of road safety management systems is possible by public effort, and safety systems have the characteristics of a pyramid, which comprises interventions to obtain a proper level of results and institutional management that supports these interventions [31]. "Institutional management" is the foundation of road safety management systems and can be defined as organizational systems, budgets, plans, laws, and systems associated with road traffic safety [8,28]. "Interventions" can be defined as influences that prevent traffic collisions in advance or reduce their severity, such as the safe design and operation of vehicles, roads, and associated facilities, as well as education, training, and public awareness for road users. Lastly, "results" addresses the number of traffic collisions, human casualties, and resulting social costs [8,28,32] (Figure 1).

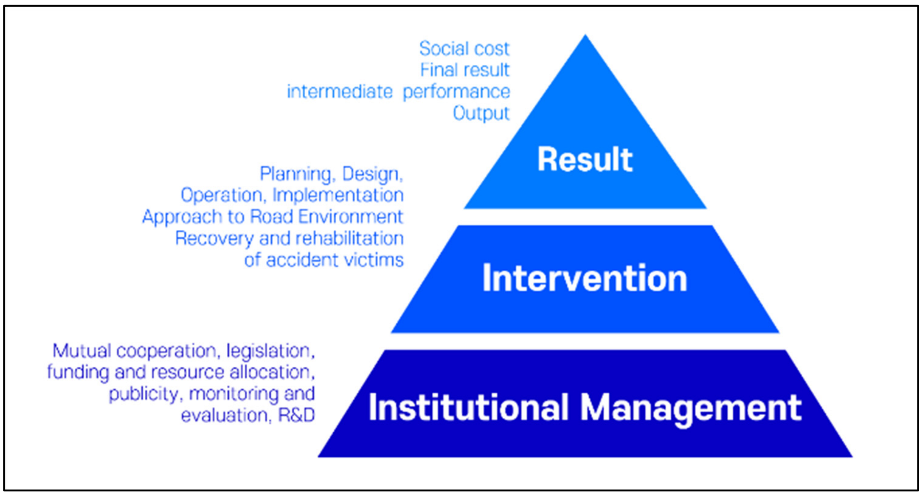

Figure 1. RSMS definition diagram.

The concepts of "results", "interventions", and "institutional management" were constructed from the PDCA perspective of RSMSs into "performance", "effect", and "improvement" (Figure 2).

The initial stages of exploration of the available road safety indices and factor exploration analysis (RSMSs) involved collecting, to the greatest extent possible, existing indicators utilized in Korea. The objective was to incorporate diverse and practical indicators, and to subsequently filter them. This process was integral to categorizing the pyramid-specific attributes of the RSMSs, and represented the phase of data collection and characteristic classification preceding the derivation of the final indicator.

Figure 2. Analysis process.

Using the indicators at the administrative-district level, we performed a cluster analysis to determine the implications of using the developed indicators for regional safety level comparison. K-means clustering was utilized for cluster analysis [33,34]. K-means clustering [35] is an analysis technique that groups n data into k clusters. It is a cluster analysis that enables the collection of data over short distances by using averages that can represent each k cluster. Clustering is the process of determining the number of clusters, setting the average value of each cluster at random, and then setting the average value with the smallest Euclidean distance as one cluster by averaging all data values and the Euclidean distance [35,36]. We used the elbow method to examine the number of clusters (final k) for which the variability within clusters decreased drastically as the number of clusters increased.

Regarding K-means cluster analysis and hierarchical cluster analysis, density-based clustering employs a methodology that clusters regions with dense concentrations of points. This algorithm can be applied to a wide range of data types for analysis, as it recalculates the average and updates the initial values. It allows for the meaningful analysis of data without requiring prior information about the internal structure of the given dataset.

4. Results

4.1. Indicator Exploration

A total of 163 indicators were extracted in Korea by classifying them according to the measurement method (e.g., observational study, statistical research, or questionnaire survey), data stability (use of existing data or conducting a separate survey), data cycle, data form (e.g., quantitative or qualitative, population or sample), detailed calculation formula, and factors (e.g., vehicles, humans, or facilities). Those indicators were standardized by eliminating redundancies, and we evaluated their relevance to the National Road Safety Master Plan. Then, the indicators were reclassified based on the hierarchy and divided into performance, effect, and improvement, and they were derived and reviewed to select the final indicators. Table 1 is an example of established safety indices, classifying them according to the measurement method (e.g., observational study, statistical research, or questionnaire survey), data stability (use of existing data or conducting a separate survey), data cycle, data form (e.g., quantitative or qualitative, population or sample), detailed calculation formula, and factors (e.g., vehicles, humans, or facilities). Indicators were standardized by eliminating redundancies, and we evaluated their relevance to the National Road Safety Master Plan. Then, the indicators were reclassified based on the hierarchy divided into performance, effect, and improvement, and they were derived and reviewed to select the final indicators. Table 1 is an example of established safety indices. Consequently, the classification was conducted based on the characteristics of indicators in Korea. Subsequently, an exclusion process was implemented to eliminate indicators that did not align with these characteristics, aiming to reduce errors in the parameter data characteristics.

Table 1. Example of an index extraction table for each domestic road safety category to select traffic safety indices.

Evaluation Indicator	Source	Measuring Entity	Measurement Method	Data Stability	Data Cycle	Data Timing	Data Form	Factor
Pedestrian crossing stop line compliance rate	Traffic safety culture index	Korea Transport Safety Administration	Observational study	Separate survey	Annual	2021	Quantitative sample	Vehicle
Rate of turn signal illumination	Traffic safety culture index	Korea Transport Safety Administration	Observational study	Separate survey	Annual	2021	Quantitative sample	Vehicle
Traffic signal compliance rate	Traffic safety culture index	Korea Transport Safety Administration	Observational study	Separate survey	Annual	2021	Quantitative sample	Vehicle
Seatbelt use rate	Traffic safety culture index	Korea Transport Safety Administration	Observational study	Separate survey	Annual	2021	Quantitative sample	Vehicle
Helmet use rate of two-wheeled vehicle users	Traffic safety culture index	Korea Transport Safety Administration	Observational study	Separate survey	Annual	2021	Quantitative sample	Vehicle
Use of mobile devices while driving	Traffic safety culture index	Korea Transport Safety Administration	Questionnaire survey	Separate survey	Annual	2021	Quantitative sample	Human
Driving under the influence	Traffic safety culture index	Korea Transport Safety Administration	Questionnaire survey	Separate survey	Annual	2021	Quantitative sample	Human
Speed-limit violation	Traffic safety culture index	Korea Transport Safety Administration	Questionnaire survey	Separate survey	Annual	2021	Quantitative sample	Human
Pedestrian crossing traffic signal compliance rate	Traffic safety culture index	Korea Transport Safety Administration	Observational study	Separate survey	Annual	2021	Quantitative sample	Human
Rate of pedestrians using mobile devices while crossing street	Traffic safety culture index	Korea Transport Safety Administration	Observational study	Separate survey	Annual	2021	Quantitative sample	Human
Jaywalking	Traffic safety culture index	Korea Transport Safety Administration	Questionnaire survey	Separate survey	Annual	2021	Quantitative sample	Human
Local governments acquired with traffic safety expertise	Traffic safety culture index	Korea Transport Safety Administration	Literature review	Separate survey	Annual	2021	Qualitative	Human

In this study, the search was performed by classifying indicators according to their individual characteristics. In the case of factors, 42 indicators were assigned to facilities, 45 indicators to humans, 50 indicators to local governments, and 26 indicators to vehicles. In terms of data forms, 36 quantitative population indicators, 85 quantitative sample indicators, and 42 qualitative indicators were classified. In the classification by stage, 40 indicators for prevention, 17 indicators for response, 28 indicators for preparation, and 78 indicators for improvement were categorized. In terms of data stability, the indicators were separated into

42 indicators for utilizing existing data and 121 indicators for a separate survey. Regarding the detailed calculation method, classifications were made for 21 observational studies, 17 literature reviews, 15 questionnaire surveys, 55 statistical research studies, 33 statistical indicators, and 22 undetermined cases.

4.2. Result of Indicator Selection

The performance category was categorized further into traffic system, road safety, vehicle safety, members, and countermeasures. This was in line with the factors outlined in the OECD's Towards Zero: Ambitious Road Safety Targets and the Safe System Approach. In the effect category, the number of road casualties (fatalities and injuries) was represented in two ways: the target achievement rate and performance achievement. Lastly, the improvement category was subdivided into YoY improvement in the detailed factors in the effect category, efforts for safety improvement, and the feedback category. In this study, however, feedback and other efforts were deemed qualitative variables. The final results are organized according to these categories in Table 2.

The final evaluation sub-indicators were chosen based on data availability, representativeness, and compatibility with existing indicators. We then normalized the derived indicators on a 10-point scale for administrative district-level comparisons. However, feedback and other efforts were evaluated as qualitative areas among the improvement areas.

Table 2. Final evaluation result for road safety indicators.

Main Category	Category	Subcategory	Evaluation Indicator	Note
Performance	Traffic system	Constitutions and statutes	Enactment and notification of road safety regulations (children's school routes/pedestrians/vulnerable road users)	Individual survey
		Organization	Percentage of road-safety-related personnel	Previous year's statistical data
		Infrastructure	① Percentage of advanced safety system introduction expenses	Previous year's statistical data
			② Percentage of zones prioritizing vulnerable road users per road length	Previous year's statistical data
	Road safety	Improvement	Percentage of local road safety environment improvement project budget	Previous year's statistical data
		Enforcement and management	Number of unmanned traffic enforcement systems installed per road length	Previous year's statistical data
	Vehicle safety	Improvement	Support for advanced vehicle safety devices	Previous year's statistical data
		Management	Support for older driver road safety projects	Previous year's statistical data
	Members	Governance	Performance of the general coordination body for road safety	Individual survey
		Education	① Percentage of personnel trained in business vehicle safety management	Previous year's statistical data
			② Percentage of personnel trained in regular road safety	Previous year's statistical data
	Countermeasures		Safety management level of business vehicles used by local governments	Previous year's statistical data

Table 2. *Cont.*

Main Category	Category	Subcategory	Evaluation Indicator	Note
Effect	Target achievement rate	National road safety indicators	Goal achievement rate of traffic collision fatalities	Previous year's statistical data
	Performance achievement	Number of fatalities	Number of fatalities per 100,000 population	Previous year's statistical data
		Number of injuries	Number of injuries per 100,000 population	Previous year's statistical data
		Consolidated index	Traffic safety culture index compliance rate (pedestrian/driving behavior)	Previous year's statistical data
Improvement	YoY improvement	Improvement in national road safety indicators	① Improvement rate in the number of fatalities per 100,000 population	Previous year's statistical data
			② Improvement rate in the number of injuries per 100,000 population	Previous year's statistical data
		Improvement in performance achievement	Improvement rate in traffic safety culture index (pedestrian/driving behavior)	Previous year's statistical data
	Feedback	Interventions	Evaluation of exemplary policy	Individual survey (qualitative indicator)
	Other efforts	Others	Other studies and efforts	Individual survey (qualitative indicator)

The indicators for each administrative district in Korea, based on 2021 data (evaluated in 2022) for performance, effect, and improvement by city and province, are summarized in Table 3. Individual indicators were aggregated under the assumption that they all carried the same weight. In terms of performance, Gyeonggi-do scored highest, followed by Busan, Seoul, Daejeon, and In-cheon. Gyeonggi-do again scored top in terms of effect, followed by Incheon, Gyeongnam, Sejong, and Seoul. Jeollanam-do ranked first for the improvement indicator, followed by Daegu, Jeolla-buk-do, Incheon, and Gwangju. In terms of the average of the three indicators, Gyeonggi-do received the highest score, followed by Incheon, Seoul, Busan, and Gwangju.

The results for each indicator, by administrative district, are shown graphically in Figures 3–5. There was no correlation between indicators, and there was no dominant indicator in each main category, according to the analysis. Consequently, there were no inappropriate indicators for the evaluation by administrative district.

Table 2 presents a concise overview of the evaluation index formulas and associated statistical metrics for each classification factor, representing the outcome of the ultimate selection of traffic safety indicators.

Table 3 provides a comprehensive summary of the study's final indicator results, offering index analysis results based on the primary categorization of 17 administrative districts.

Table 3 also provides a concise summary of indicator results for administrative districts in Korea. It is based on 2021 data related to performance, effect, and improvement across both cities and provinces, with evaluations conducted in 2022. These individual indicators were aggregated with an assumption of equal weighting.

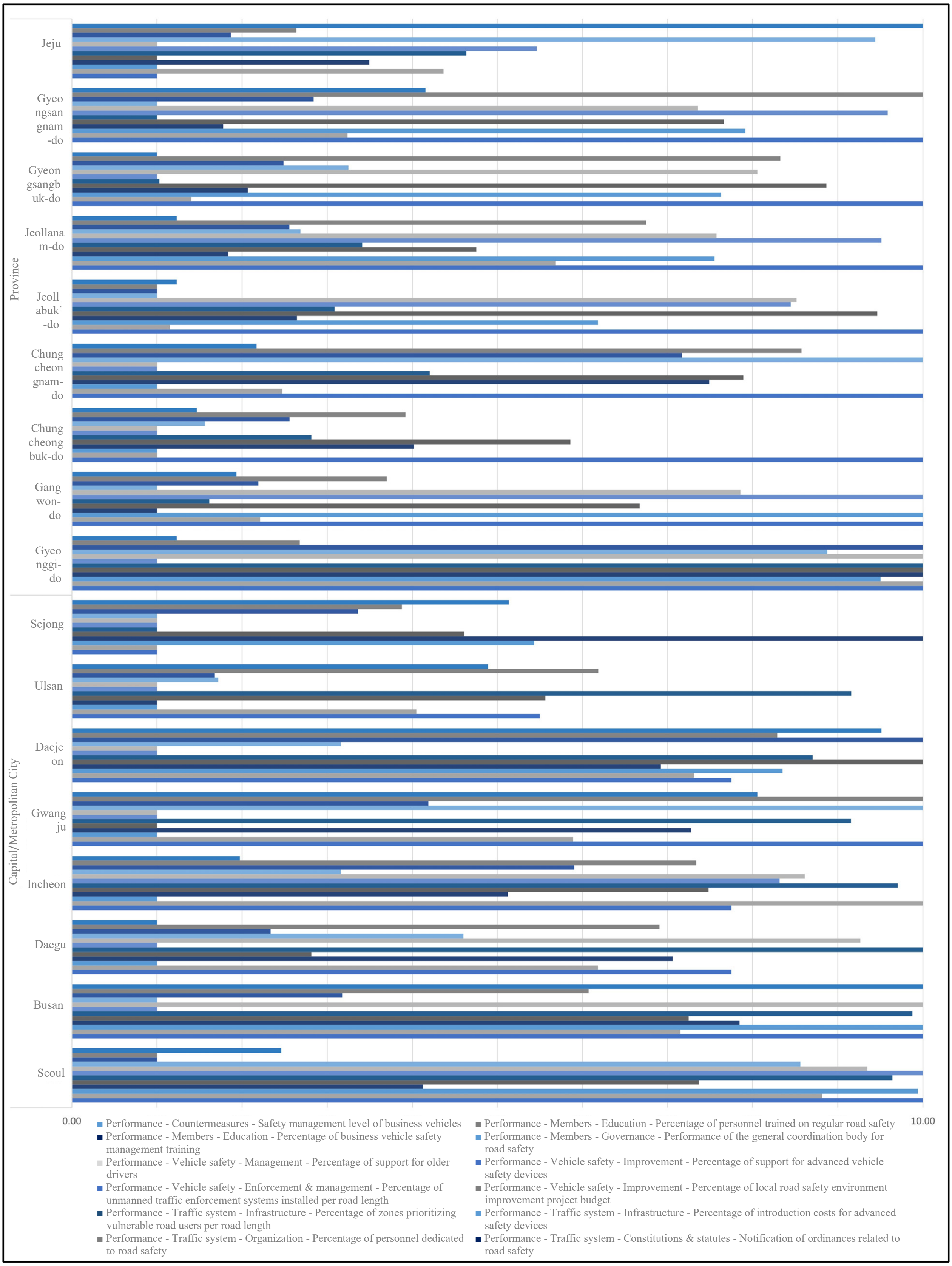

Figure 3. Individual indicators in performance category by metropolitan city and province.

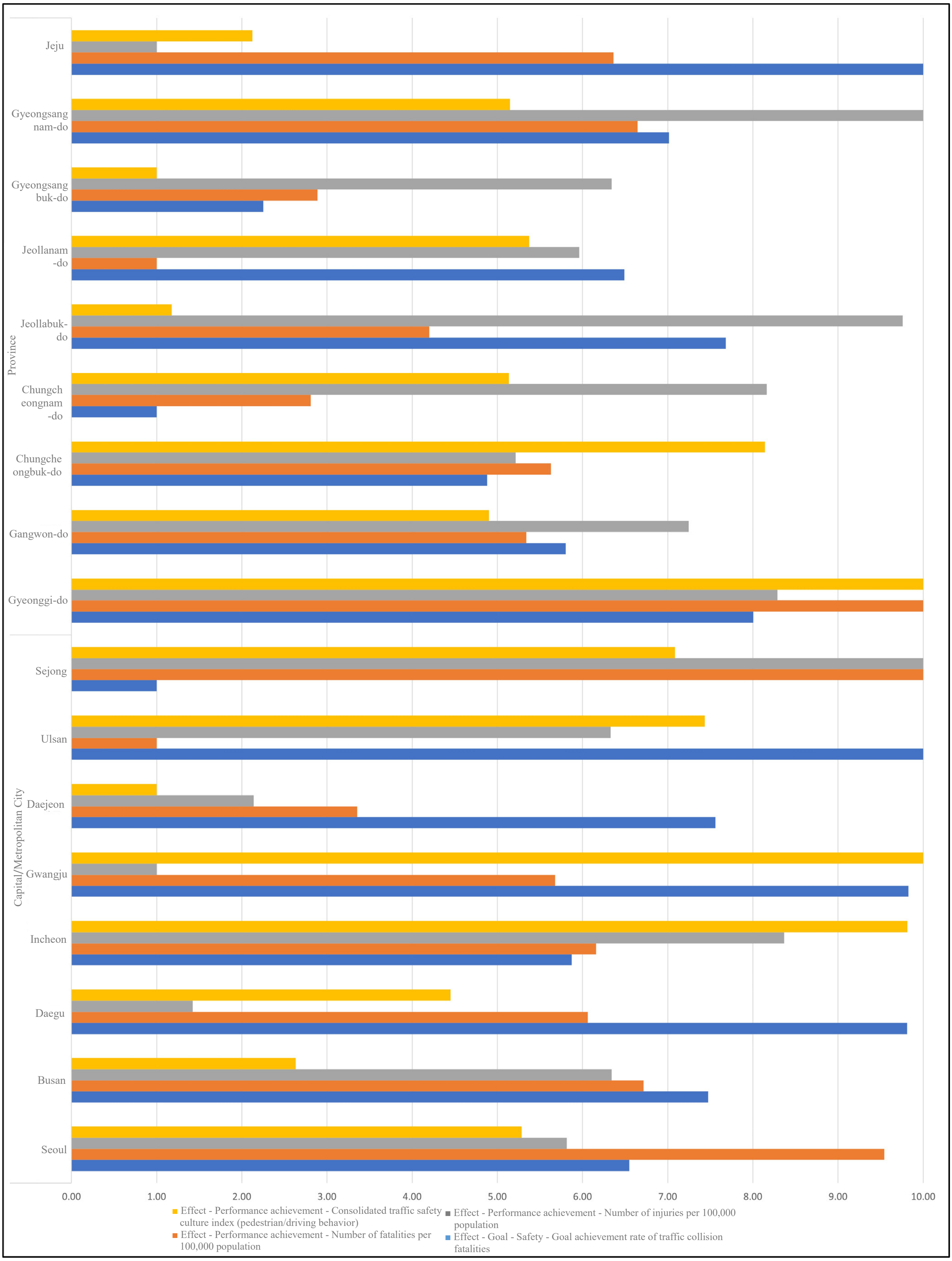

Figure 4. Individual indicators in effect category by metropolitan city and province.

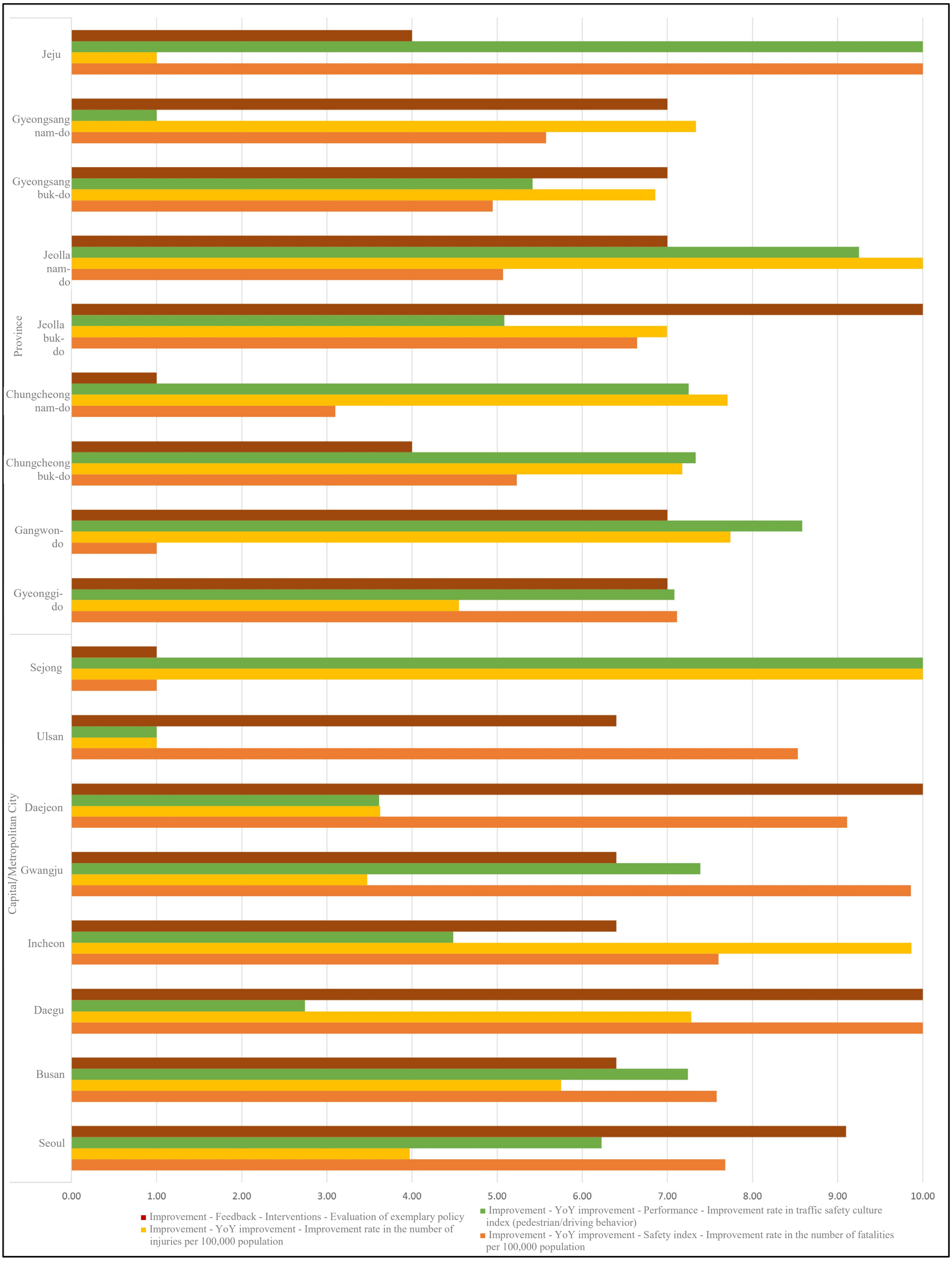

Figure 5. Individual indicators in improvement category by metropolitan city and province.

Table 3. Table of performance, effect, and improvement indicators by city and province.

City/Province	Performance	Effect	Improvement
Seoul	6.86	6.80	6.74
Busan	6.95	5.79	6.74
Incheon	6.36	7.55	7.09
Gwangju	5.71	6.63	6.78
Gyeonggi-do	7.77	9.07	6.44
Gyeongsangnam-do	5.54	7.20	5.23
Ulsan	3.56	6.19	4.23
Sejong	3.20	7.02	5.50
Chungcheongbuk-do	3.02	5.97	5.93
Daegu	4.99	5.44	7.51
Gangwon-do	4.85	5.82	6.08
Jeollabuk-do	4.48	5.70	7.18
Jeollanam-do	5.30	4.71	7.83
Jeju	3.83	4.87	6.25
Daejeon	6.83	3.51	6.59
Chungcheongnam-do	5.25	4.28	4.76
Gyeongsangbuk-do	4.59	3.12	6.06

Figures 3–5 correspond to the calculated results of individual indicators within each administrative district, categorized under performance, effect, and improvement. These figures serve as detailed supplements to the information presented in Table 3, above.

Upon implementing the elbow method (Figure 6), we established four clusters for k-means clustering. In Figure 7, the k-means clustering analysis results for the three categories—performance, effect, and improvement—are depicted on a three-dimensional graph. There are four clusters in total: Cluster 1 (Seoul, Busan, Incheon, Gwangju, Gyeonggi-do, and Gyeongsangnam-do); Cluster 2 (Ulsan, Sejong, and Chungcheongbuk-do); Cluster 3 (Daegu, Gangwon-do, Jeollabuk-do, Jeollanam-do, and Jeju); and Cluster 4 (Daejeon, Chungcheongnam-do, and Gyeongsangnam-do).

In Figure 8, the k-means clustering of the three categories is the result of resetting the city and provincial characteristics of population, budget, and road area as three axes of a three-dimensional graph. Despite being the result of conducting clustering analysis for each performance, effect, and improvement categorized in this study, the final value exhibited characteristics of division.

Thus, the 17 administrative districts of Korea were divided into four groups: Cluster 1 (six cities and provinces), Cluster 2 (three cities and provinces), Cluster 3 (five cities and provinces), and Cluster 4 (three cities and provinces). The population proportion for each group was as follows: 66.09% (Cluster 1), 5.99% (Cluster 2), 15.92% (Cluster 3), and 12.00% (Cluster 4). The budget proportions were 68.11% (Cluster 1), 4.49% (Cluster 2), 16.74% (Cluster 3), and 10.65% (Cluster 4). The road areas were 39.78% (Cluster 1), 8.65% (Cluster 2), 31.03% (Cluster 3), and 20.54% (Cluster 4). Table 4 displays the populations, budgets, and road areas by city and province for each cluster, while Table 5 displays the sum and proportion of each group's characteristics.

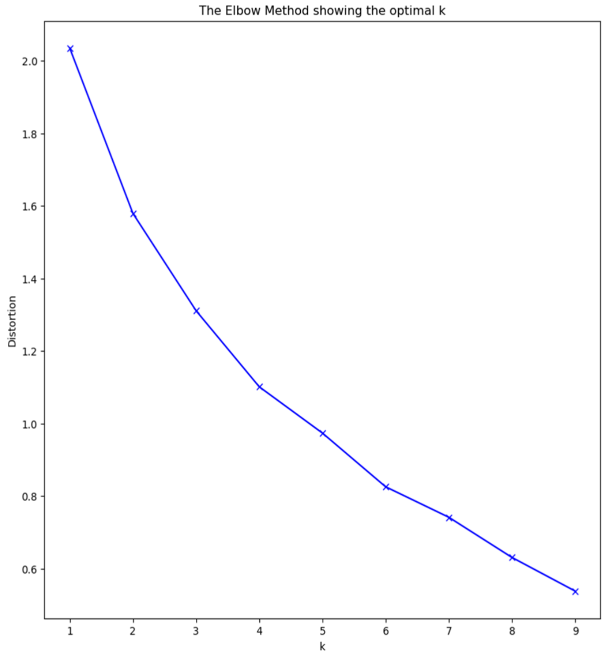

Figure 6. Optimal k using the elbow method.

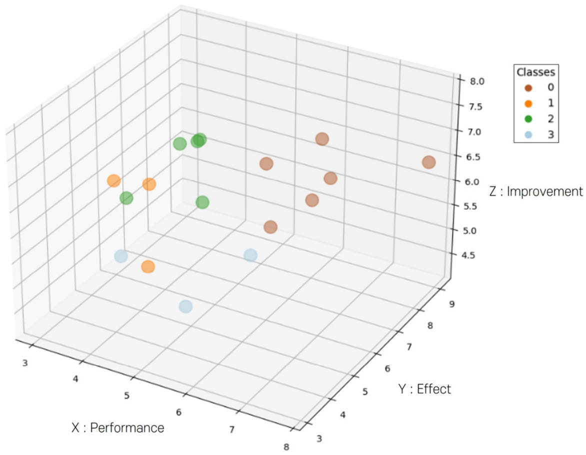

Figure 7. K-means clustering analysis (3-dimensional diagram) based on the characteristics of Indicators (Performance, Effect, Improvement).

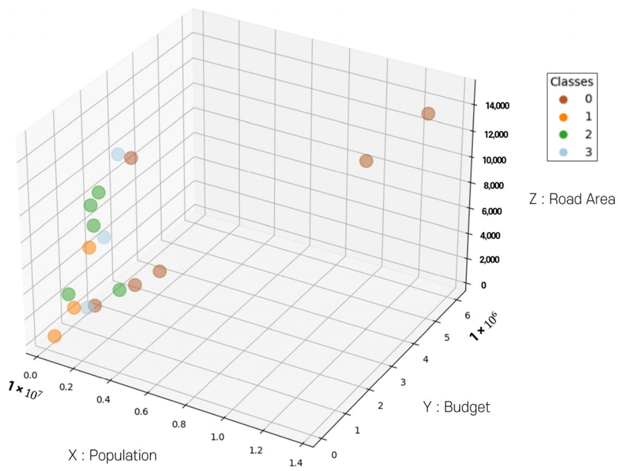

Figure 8. K-means clustering analysis (3-dimensional diagram based on the characteristics of each city and province).

Table 4. Cluster analysis results based on the features of each city and province.

City/Province	Cluster Number	Population	Budget	Road Area
Seoul	0	9,509,458	6,003,883	8359
Busan	0	3,350,380	2,093,815	3416
Incheon	0	2,948,375	1,409,321	3317
Gwangju	0	1,441,611	904,784	1879
Gyeonggi-do	0	13,565,450	5,175,480	14,813
Gyeongsangnam-do	0	3,314,183	1,126,505	13,645
Ulsan	1	1,121,592	347,315	2544
Sejong	1	371,895	90,471	423
Chungcheongbuk-do	1	1,597,427	664,633	6915
Daegu	2	2,385,412	1,208,536	3015
Gangwon-do	2	1,538,492	805,755	9857
Jeollabuk-do	2	1,786,855	723,581	8568
Jeollanam-do	2	1,832,803	914,448	10,776
Jeju	2	676,759	456,551	3217
Daejeon	3	1,452,251	615,445	2226
Chungcheongnam-do	3	2,119,257	871,339	7588
Gyeongsangbuk-do	3	2,626,609	1,126,505	13,645

Table 5. The sum and ratio by features based on clustering.

Classification	Population		Budget		Road Area	
	Total	Proportion	Total	Proportion	Total	Proportion
Cluster 1	34,129,457	66.09%	16,713,788	68.11%	45,429	39.78%
Cluster 2	3,090,914	5.99%	1,102,419	4.49%	9882	8.65%
Cluster 3	8,220,321	15.92%	4,108,871	16.74%	35,433	31.03%
Cluster 4	6,198,117	12.00%	2,613,289	10.65%	23,459	20.54%

5. Conclusions and Future Research

Local governments and other local road safety management stakeholders have developed indicators capable of objectively monitoring safety levels, evaluating effects, and constantly assessing the degree of improvement. We created a local government safety performance index based on RSMS criteria. We chose indicators that reflected the PDCA structure and accounted for institutional management, interventions, and results. Based on this, this study selected indicators explaining institutional management, intervention, and results in RSMSs. We reflected the factors outlined in OECD's Towards Zero: Ambitious Road Safety Targets and the Safe System Approach, which are traffic system, road safety, vehicle safety, members, and countermeasures. We made academic contributions to the development of the safety index by creating comprehensive indicators that can be systematically evaluated as individual indicators or macro indicators.

Safety-related input resources were evaluated in terms of performance, whereas the level of accomplishment was visualized in effect. In terms of improvement, both enhancement efforts and the effect relative to the previous year were reflected. Additionally, we made these indicators comparable by region to determine the level of safety. However, as individual indicators were reflected with the same weight, future research on the composition of an evaluation system that reflects the significance of each indicator will be necessary.

There was no correlation between the indicators and the population, budget, or road area by administrative district. The results were consistent with common knowledge, in which safety-related plans are specific. The distinction between the highest and lowest administrative districts was clearly illustrated, and the distribution was appropriate. It was also found that no particular indicators had a significant impact on the overall result in the major category or the overall index. Therefore, it is believed that a suitable index for evaluating the region's road safety has been developed. Following this, we anticipate that future research on the validation and enhancement of indicators will take place via annual evaluation. Regarding the indicators substituted in this study, it is noteworthy that the research stage adhered to the effectiveness and practical characteristics, with a particular emphasis on performance evaluation. This emphasis is underscored by the inclusion of actual indicators utilized by public institutions, such as the Korea Transportation Safety Authority.

In Korea, it was determined that safety-management-related administrative districts constitute clusters. They were classified into clusters with good performance, effect, and improvement; clusters in which the safety level was appropriately maintained despite low performance and improvement; clusters with a medium level of performance, effect, and improvement; and clusters in which all performance and effect indicators were low. From the safety-management perspective, these clusters were categorized, in this study, as groups with high performance, caution (potential risk), room for improvement, and high interest. Due to the fact that the results of this study do not reflect the significance weight for performance, effect, and improvement, it is necessary to develop an evaluation system that reflects the government's policy direction in the institutionalization process.

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