Digitalization for the environmental impact assessment of railway projects using drones and lidar

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Abstract: Environmental impact assessments of Korea's railway projects are currently presented qualitatively and follow guidance in the Eco-friendly Railway Construction Guidelines (2015). Quantitative prediction and evaluation are limited due to limitations conducting literature research or making uniform measurements. Recent developments in the quantification of assessment data emphasize the collection of environmental with Fourth Industrial Revolution technologies such as drones, lidar, big data, and artificial intelligence (AI). In this study, we reviewed the limitations of existing evaluation methods for six key evaluation items for the assessment of railroad projects (air quality, water quality, ecology, topography, noise and vibration, and scenic value). For the first time in Korea, we developed a digitalization plan that will secure quantitative data through drones and lidar for environmental impact evaluations of railroad projects. Based on our results, a preemptive response system can be established for the digitalization of environmental impact assessment for the railway business. In the future, it will be necessary to apply the technologies used in this study to collect continuous time-series data based on the methods established in this study, and to implement specific prediction models.

Keywords: Environmental impact assessment, Railroad project, Digitalization, Digital platform, Drone-lidar.

Introduction

The Korean railroad network is a large-scale linear project, and continuous development is being carried out on the network to increase track capacity. The 4th National Rail Network Construction Plan (Ministry of Land, Infrastructure and Transport, 2021) stated that there is a need to expand track capacity and secure infrastructure to provide new high-speed rail services. However, various environmental problems have arisen during the operation and construction of railway projects. In the case of the Jiri-Mountain Railway, delays occurred due to a variety of environmental and ecological problems. Noise pollution caused by the railway project is frequently brought up as a key environmental problem along the railway's operating route. In addition, there is a need to prepare measures to address environmental problems caused by the construction of underground urban railways, which include changes in underground air quality and groundwater levels.

Environmental impact assessments of railway projects in Korea are based on the Environment-Friendly Railway Construction Guidelines (Ministry of Land, Infrastructure and Transport, Ministry of Environment, 2015) These guidelines are presented qualitatively. Limitations of the available literature and a lack of uniform measurements constrain the ability of assessors to evaluate environmental problems and make quantitative predictions (Kim et al., 2020). In addition, there are no objective data on environmental and ecological problems that may arise during railroad construction. Accordingly, to overcome the limitations of existing evaluation methods and to conduct scientific verification, quantitative data must be collected and datasets must be constructed. Recently, Fourth Industrial Revolution technologies such as drones, lidar, big data, and artificial intelligence (AI) have been used in various fields. The environmental assessment of railroad projects could benefit from the deployment of these technologies to collect environmental data and to build prediction models of environmental effects (Lee et al., 2015; Gyeonggi Research Institute, 2021).

In Korea, the issue of building integrated platforms, such as the digitalization of Social overhead capital (SOC) business and digital twin national land has been raised since 2020, and attempts have been made to build systems in various fields. In many countries, predictions and action plans are based on actual data surveys, which enable planners to efficiently respond to and manage environmental issues. Planning processes may include the preparation of 3D digital platforms and platform services that provide national-level environmental information. In Korea, the Environmental impact assessment support system (EIASS) platform provides documents on environmental impact assessment related agreements for 17 development projects, including railroads. The platform provides some geographic information services based on existing public data. However, there are many cases where data on target sites, results generated at the desired scale, or time-series data are missing.

There are practical limitations to conducting comprehensive and detailed analysis through field surveys alone. To compensate for these shortcomings, drones can be used to collect environmental data quickly and easily in areas that are difficult to access. Based on such data, a basis for objective judgment can be prepared. A photogrammetric technique using drone images to generate high-quality 3D spatial information may facilitate the prediction and mitigation of environmental impacts based on high resolution images (Dong & Cho, 1992; Korea Environment Institute, 2019; Song, 2021; Kang & Lee, 2022, Kim, 2018; Park, 2021; Ko et al., 2021; Cho et al., 2020). Also, if there is an EIASS platform that handles domestic environmental impact assessment, the US EPA platform, Germany's EIA platform, and Japan's EADAS platform are in operation. Attempts have been made to use modeling to generate digital twins of entire cities, as is the case for Virtual Singapore (National Research Council of Science & Technology, 2023). However, although there are cases of digital twins built with data collected by the latest technology, there are no assessments of model limitations, of specific data collection methods, or of platforms built for the environmental impact assessment of railway projects.

Previously, research on noise has been mainly conducted in relation to railways (Dzhambov & Lercher, 2019; Hegewald et al., 2020; Beutel et al., 2016; Clark et al., 2020; Koo, 2010). In this study, we reviewed the existing evaluation methods and contents of six key evaluation items that are considered when assessing the environmental impact of railroad projects. We also collected time-series data using Fourth Industrial Revolution technologies such as drones and lidar. Based on these data, quantification methods and manuals to enable rapid prediction and evaluation were presented for the first time in Korea. In addition, a future-oriented response system was established for the digitalization of environmental impact assessments for railway projects. Our analysis suggested that individual prediction models for each item will have to be implemented in the future.

Materials and Methods

Research site

In this study, we targeted the area around the Osong Railway Comprehensive Test Line, which is the only test line in Korea in the Figure 1. The test line is currently structured in the form of a half loop. A preliminary feasibility study recommended that it be constructed in the form of a circular line, and our target section of the line will undergo an environmental impact assessment in the future.

A study was conducted to collect data before the beginning of the development on this section of line. The optimal location was selected to evaluate the six core evaluation items of the environmental impact assessment for the railway project, and technologies such as drones and lidar were used to provide quantitative data for the environmental impact assessment and to evaluate the potential use of digitalized evaluation methods.

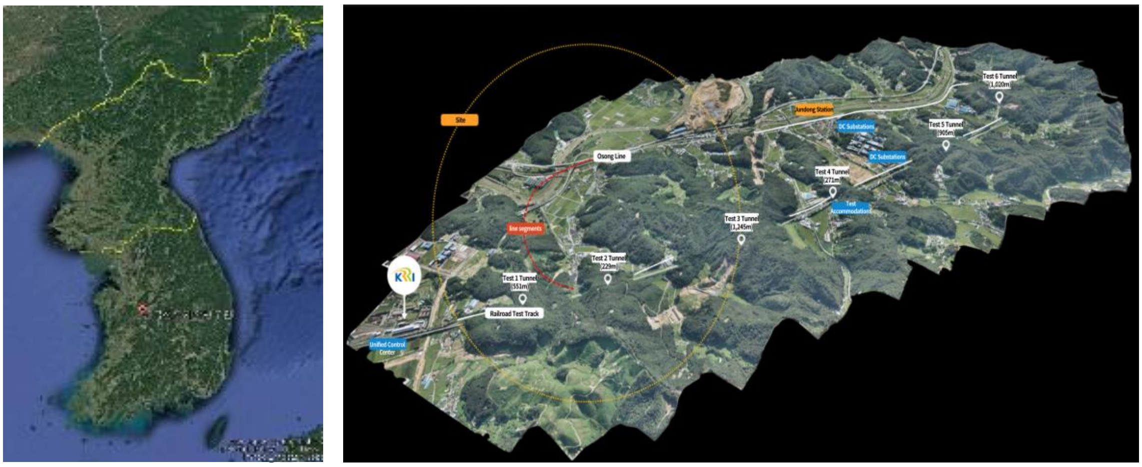

Fig. 1. Location and current status of the study site.

Measurements

Environmental impact assessments are conducted in advance of railway construction projects to ensure environmentally sound and sustainable development. Several types of environmental impact assessment are recognized, including strategic environmental impact assessments, environmental impact assessments, and small-scale environmental impact assessments. The environmental impact assessment of railway projects consists of 21 items in six major areas and is based on the Environment-Friendly Railway Construction Guidelines (2015). Air quality, water quality, topography and geography, ecology (fauna and flora), noise and vibration, and scenic value were reviewed as key evaluation items. We investigated the current evaluation methods applied to these six items, quantitatively derived the limitations of these existing methods, suggested environmental variables that needed to be confirmed, and evaluated whether digitalization was possible.

Measurement equipment

Both unmanned aerial vehicles (UAVs) and lidar equipment were used to collect environmental data at the test site and to build a digital twin model in the Figure 2. The UAVs used in the study were Inspire2 (DJI

Innovation Company Inc., Shenzhen, China), Mavic2pro (DJI Innovation Company Inc., Shenzhen, China), and Matrice 300 RTK (DJI Innovation Company Inc., Shenzhen, China). Additionally, Matterport Pro3 (Matterport Inc., CA, USA) and Leica BLK360 (Leica, Swiss) (i.e., BLK360) were used as portable lidar equipment to collect point cloud data. Matterport Pro3 and BLK360 are Wi-Fi capable and can perform laser scanning 360° horizontally and 300° vertically. The Matterport Pro3 has a scan speed of 100,000 points per second, and the BLK360 has a scan speed of 360,000 points per second. This monitoring technique can be implemented by converging 2D Virtual reality (VR) images and 3D models, enabling multifaceted image monitoring.

a. UAV (Inspire2) b. Camera (Zenmuse X5S) c. Matterport pro3 d. BLK 360

Fig. 2. UAV, lidar, and VR equipment.

Results and Discussion

Limitations of environmental impact assessment of existing railway projects

The railroad project is a large-scale linear project, track capacity continues to increase, and environmental problems related to railroad construction frequently arise. The project was delayed for several years due to requests to provide supplemental data for the environmental impact assessment, resulting in excessive social and economic costs.

From an environmental perspective, the railroad project has had a significant impact on air quality, topography and geology, water quality, ecology (flora and fauna), natural environmental assets, noise, vibration, and landscape. Although these environmental impacts should be comprehensively reviewed during evaluation, existing evaluation methods consist of simple literature surveys or uniform field surveys. The information and data provided by these methods do not provide an adequate basis to assess the environmental impacts caused by railroad construction. Therefore, these methods cannot be used as a concrete basis for decision-making.

Air quality is measured using statistical data and automatic measurement data gathered by the Ministry of Environment near the target site. Water quality is measured through statistical data and data that are stored in the water environment information system. However, air quality and water quality are measured within administrative district boundaries, causing errors due to the varying distances between actual measurement sites and the planned construction site. Topography is based on images captured by satellites, which enable large areas to be observed in a short period of time. However, the resolution of the captured images is low, making it difficult to obtain detailed information from satellite images. Because satellites occupy fixed orbits, it is difficult to determine patterns of change across the observation area over time. Data on flora and fauna are gathered at points expected to be directly affected by the construction of facilities.

In recreational landscapes, cameras sensitive to wavelengths compatible with human vision are deployed at points where direct impacts caused by facilities or changes in the landscape are expected. However, this method requires a lot of time for investigation and prediction and is poor at capturing continuously changing variables such as design changes to railroad facilities. Overall, current evaluation methods impose limitations on the quality of data that can be collected for each item in the environmental impact assessment. Furthermore, the variables and measurement errors that occur are factors that can reduce the reliability of the results.

We propose that spatial mapping techniques, which apply digital remote sensing technologies such as drones and lidar, can be used to overcome the limitations of existing evaluation methods. These techniques can be used to increase both work efficiency and accuracy. In particular, there is a great need to collect quantifiable time-series data on environmental items through the convergence of Fourth Industrial Revolution technologies such as

Building information modeling (BIM), drones, lidar, 3D scanning, and AI algorithms. It is therefore necessary to formalize the data collection method for each item, prioritizing the environmental assessment key evaluation items.

Table 1 presents a comparison of current evaluation methods and the proposed methods derived from the results of the present study for six key environmental items used in impact assessments of railroad projects.

Table 1. Digitalization of railroad project environmental impact assessments.

Division	Existing method	Proposal method
Air quality	- Literature research	- Operation of an air measurement device (Sniffer4D) mounted on a drone - Collection of time-series data according to distance and height
Water quality	- Literature research - On-site investigation	- Sampling using an unmanned surface vehicle or underwater drone - Collection of multi-period time-series data
Topography and geology	- Literature research - Site survey	- Stepwise data acquisition using drones and lidar - Collection throughout railroad projects before construction, during construction, and at the three construction completion stages
Ecology (fauna and flora)	- Literature research	- Digital habitat environment survey using drones and fixed lidar - Two-and three-dimensional data of biodiversity, species distribution, habitat, and connectivity
Noise and vibration	- Literature research - Status measurement - For noise, 2D railroad noise prediction and evaluation	- Measurements using drones with an attached noise meter - Collection of data according to distance and height - For noise, three-dimensional railroad noise prediction considering topography and stationary building distribution
Scenic value	- Status survey - Selection of viewpoints and prediction of landscape changes using photography	- Introduction of the landscape information model concept - Three-dimensional viewpoint selection and landscape change prediction using lidar

Digitalization of environmental impact assessments of railway projects

Air quality digitalization

When investigating air quality, literature research is not appropriate due to the distance from existing measurement sites to the target site. Time-series data do not produce adequate measures of current air-quality status under the Air Quality Pollution Process Test Standard. It is possible to measure air quality by attaching air quality measurement equipment to mobile measurement vehicles. However, in the case of railway development sites, there are many geographical conditions that inhibit vehicle movements, and for this reason, we propose to attach air quality measurement equipment to drones. In addition to Sniffer4D, air quality measurement equipment can be used to collect data by attaching air quality sensors to drones. Currently, the availability of time-series data is limited, and the impacts of distance, altitude, and the presence or absence of soundproof walls on data collection were explored for the railway operation section. Based on this investigation, a GIS-based two-dimensional map was constructed in the Figure 3. We identified methods for collecting air quality time-series data, which environmental variables should be identified, and whether the variables needed actual review through actual measurements.

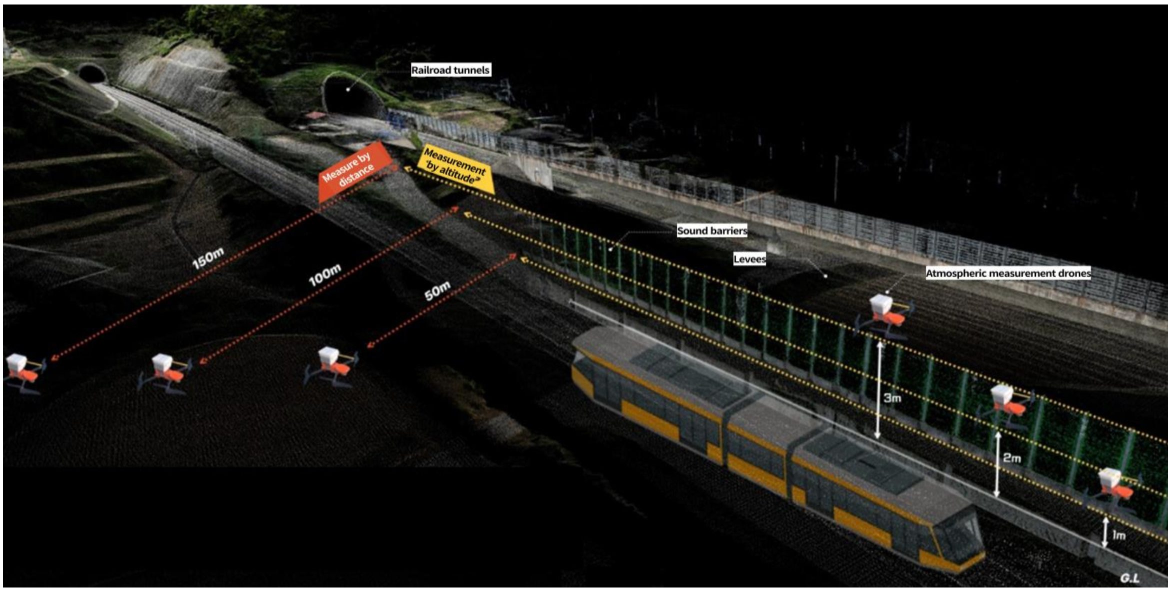

Fig. 3. Design of impact measurement by distance and altitude to measure air quality.

We measured concentrations of fugitive dust generated during railway operations according to the distance from the line and altitude where samples were taken. Concentrations of PM2.5 and PM10 were found to be higher at a distance of 60 m than at 20 m or 40 m. At a distance of 60 m, it was confirmed that concentrations at 1–2 m altitude were higher than those at 3 m altitude. Concentrations of fugitive dust peaked between 3 p.m. and 6 p.m. Concentrations of PM10 and PM2.5 were found to be highly correlated with humidity, as well as with temperature and wind speed, so there is a need to comprehensively review these environmental variables. In addition, measurement distances of 80 m and 100 m were close to the office and had a lot of vehicle movement, and for this reason, fugitive dust concentrations were high in the morning.

In the absence of a soundproof wall, PM10 and PM2.5 concentrations were relatively lower than under the 40–60 m condition, even between 3 p.m. and 6 p.m., when the number of trains was relatively high. This can be derived from the fact that the distance in question is not affected by soundproof wall. We further explored the distribution of fugitive dust as a function of distance from the rail line using interpolation. This technique showed that the presence or absence of a soundproof wall made little difference to dust concentrations in the Figure 4. Accordingly, it is necessary to establish higher soundproof walls, and we propose to use a filter system that can absorb flying dust. These measurement techniques and structures can therefore assist in the establishment of air-quality standards by collecting time-series data in the field.

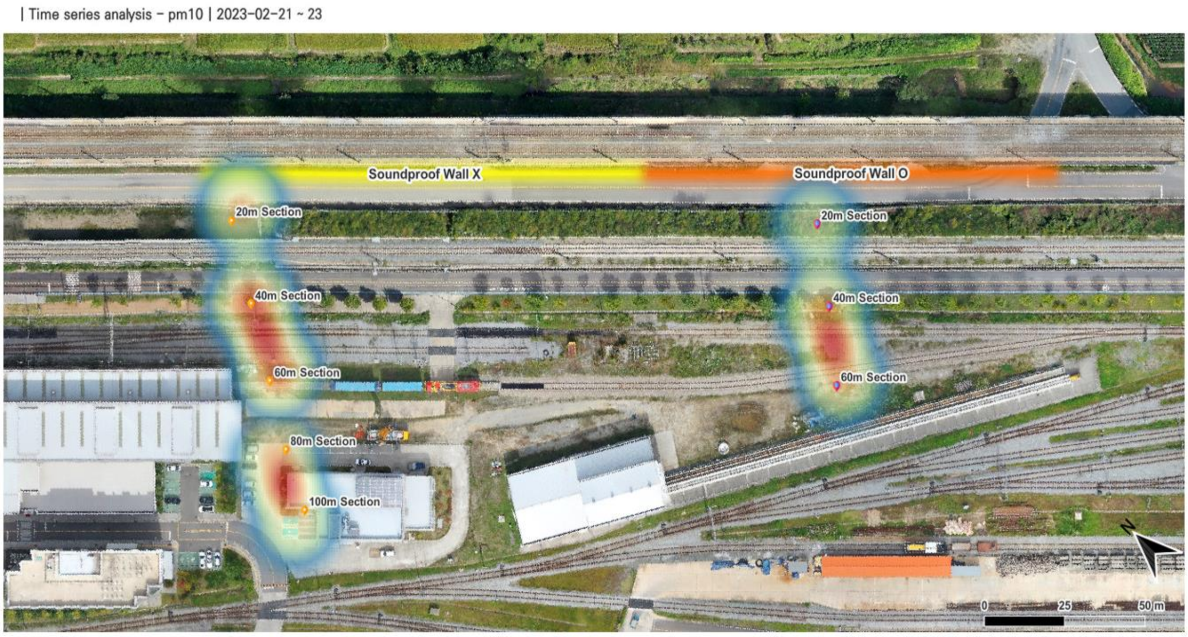

Fig. 4. Effect of fine dust on distance depending on the presence or absence of a soundproof wall.

When making predictions and evaluations of the atmosphere, microclimatic items must also be checked. The Korea Meteorological Administration provides observations of temperature, perceived temperature, precipitation, probability of precipitation, wind, and humidity. Although the number of Korea Meteorological Administration observatories continues to grow, there are only about 550 observatories across the country, which makes detailed mid- to long-term monitoring regions impossible. Although these data can be used for simulation, accuracy decreases at smaller scales. When assessing the effects of railroad operations on the surrounding environment, it is therefore necessary to collect and review data on the microclimate. Based on this realization, we conclude that

CFD-based simulations would be a necessary precondition for making predictions. For example, we measured changes in wind speed and temperature change before and after development, depending on track use. These results can be used as the basis for adjustments to the form of buildings and facilities in the Figure 5. We conclude that it is necessary to measure changes in wind speed and direction due to railway development and to measure the effects of subsequent wind-reduction techniques, as shown in predictive simulations.

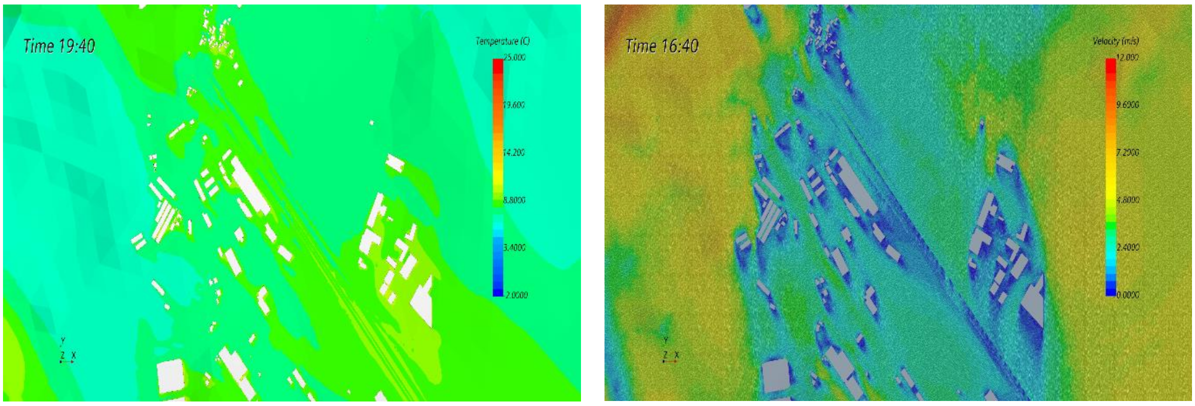

Fig. 5. CFD analysis of temperature and wind speed based on actual data around the operating line: (left) temperature change; (right) wind speed change.

Water quality digitalization

When analyzing water quality, the impact of the project was modeled based on data reported in the existing literature and on field surveys. Civil engineering work such as railway construction, bridge construction, and tunnel excavation is expected to generate outflows of soil particles and various water pollutants. Impacts from non-point sources of pollution are also expected during rainfall runoff during operations. For railroads, it will be important to review the impact of pollutants generated from platforms, maintenance facilities, railroad bridges, and tunnels on the surrounding water environment.

When conducting a survey based on the status of the water system and the influence of groundwater, the effects of the surrounding terrain can be reviewed using drones and lidar. It is also necessary to evaluate the impacts of water pollution caused by the inflow of pollutants from railway projects and to consider the continuous water-quality monitoring systems of major pollution generating facilities. The water quality impact assessment system can be based on these data. Digital monitoring technologies for predicting industrial impacts on water quality, such as automatic water quality measurement devices, drones, and satellites can be applied to evaluate the impacts of non-point pollution from rainfall on nearby surface water systems and groundwater. However, water quality impact assessment technology must be applied at a scale that is appropriate to the nature and characteristics of railroad business facilities and branches. We propose that target areas for measurement should be selected within a radius of 0.5–1.0 km of the central axis of the planned railway site. The impacts of soil runoff and non-point pollution sources would then be based on drone- and lidar-derived time-series data from the surrounding terrain. Because physical samples must be collected to assess water quality, a sample collection process using an unmanned surface vehicle (USV) with a coordinate system will be necessary in the Figure 6. Changes in water quality can then be expressed in 2-dimensional and 3-dimensional maps as part of a GIS system, which will facilitate their application to environmental impact assessments of railway projects.

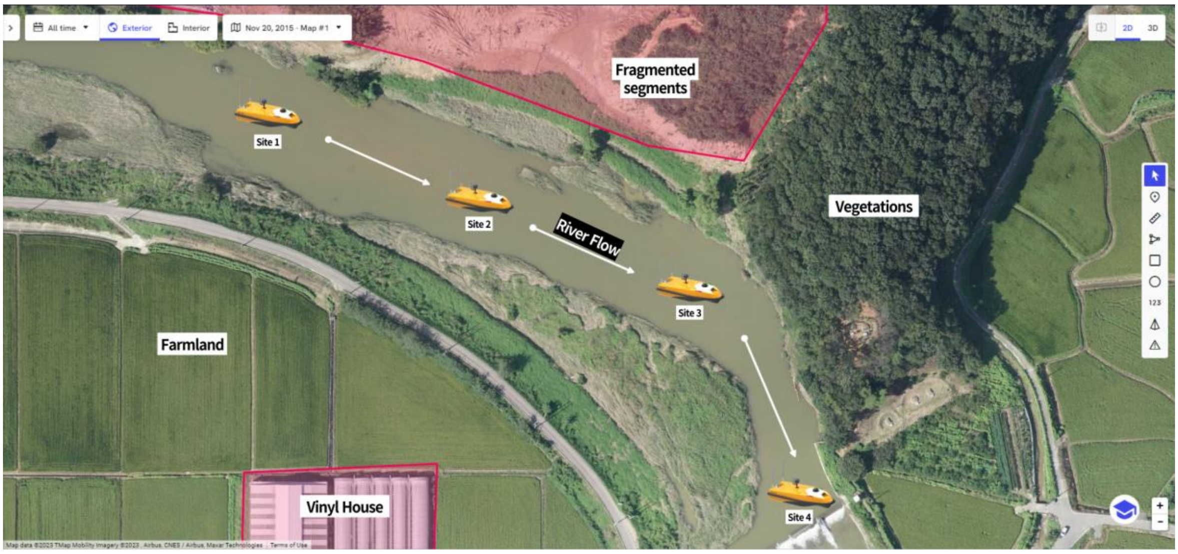

Fig. 6. Presenting a design for a water quality digitalization method.

Ecology digitalization

There are limitations on the ability of literature reviews and field surveys to accurately measure the status of flora and fauna in the area surrounding a railway project route. The seasonal distributions of flora and fauna should be known, and there are limitations in relying on the National Natural Environment Survey to determine the seasonal characteristics of species.

There is a need to comprehensively check relationships between topography and ecological characteristics of the area surrounding a project. To digitalize data on species communities, it is necessary to evaluate habitat requirements of animals and plants using VR and other technologies, and these assessments should be based on realistic data about the large space around the railway project site. Furthermore, it will be necessary to compile various evaluation results, such as species distribution, habitat suitability and connectivity, and to fuse them with digital data. Although image is meaningful for VR-type visualization, from an analytical perspective, compatibility with various tools such as GIS and BIM must be reviewed. For legally protected species, and alternative, compensatory habitats may need to be presented. These alternative scenarios can be presented in VR. We propose to conduct a digital vegetation survey based on lidar, and to predict habitats and migration routes of species or population based on high-resolution aerial maps and infrared detection cameras. When predicting the ecological impacts, it will be possible to examine the impacts of the railway project on biodiversity and the surrounding ecosystem, and to use this assessment to minimize ecological disruption in the Figure 7.

Fig. 7. Measures to secure and digitalize time-series data on ecological variables.

Topography and geology digitalization

Some literature reviews and field surveys have been conducted to measure topography and surficial geology. It is possible to analyze contour lines, elevation, slope, and direction of terrain through updated information at various scales obtained through drones or lidar. Data collected through existing satellites are limited in their ability to collect data at desired locations and times. By using drones and lidar technology, accurate location results can be obtained. Because very high-resolution results can be obtained, these data can be processed and used for research and analysis. For example, by quickly and accurately securing topographical time-series data through drones and lidar, changes due to railroad establishment can be visually confirmed and can therefore contribute to the digitalization and quantification of topographic geology in the Figure 8.

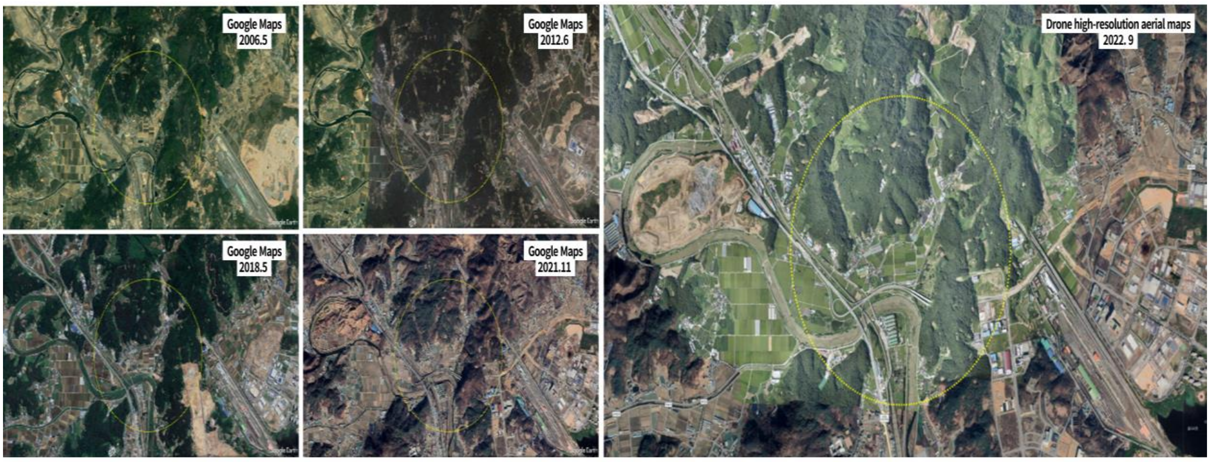

Fig. 8. Confirmation and digitalization of terrain changes using drones.

Noise digitalization

Research has principally been conducted on noise generated from trains, and there is a lack of case studies that continuously collect data on environmental noise in target areas of business routes. When drones are used to measure noise in railway projects, measurements can be made over a wide target area. The noise of the drone itself is also recorded, and so drone-noise corrections must be applied. If predictions and impact assessments for 2D railway noise have been made in the past, 3D railway noise during railway operation may be predicted from 2D data after accounting for topography and building distribution.

Noise measurements are generally made for more than two hours during the day and night, based on environmental pollution process test standards. Background noise is measured three times for more than five minutes each time. The equivalent noise levels for five minutes and one hour are acquired and then analyzed based on maximum noise levels, and the analysis is performed using the K-noise technique during comparative analysis. Verification can be performed through comparison with existing traditional methods of noise measurement, and the results measured by attaching a silencer to the drone.

To obtain time-series data on railway noise, it is necessary to comprehensively review the variables that need to be measured, including train operation speed, the presence of soundproof walls, and the impact of each separation distance. These variables can then be analyzed for significance. In this study, we installed noise meters on track sections where soundproof walls were installed and sections without soundproof walls. We compared noise levels across operating hours, and secured time-series data according to the distance to identify noise fluctuations.

The effects of environmental noise by distance from tracks and infrastructure were confirmed. We found that attaching a silencer to a drone enabled us to secure data in areas that were difficult for ground-based field crews to access. In particular, when attaching a silencer to a drone, to minimize the effects of the drone's engine noise, we hung a noise meter at a certain distance from the drone (e.g., 8 m) (Kim et al., 2023), and set the basic noise value generated by the drone to the default value. Analysis was performed based on the data collected in the Figure 9.

The issue of health effects due to low-frequency noise has been the subject of recent research, and the World Health Organization suggests that the effects of low-frequency noise may be more serious than those of general noise. Guidelines have therefore been established to effectively manage noise generated in low-frequency wavebands in other fields. There is a need to prepare in railway field. Low-frequency noise caused by railway bridge vibrations occurs. It is therefore necessary to understand the characteristics of low-frequency noise on railway projects, to evaluate its severity, and produce guidelines for its inclusion in environmental impact assessments. Supplemental research should be done to quantify the stress produced by railway-generated noise on the human body using brain waves and pulse waves.

Fig. 9. Method of attaching a noise meter to a drone related to environmental impact assessment of railway noise.

After we collated the data collected during train operations, we reviewed variables such as no stopping or stopping, up and down, and the presence or absence of soundproofing. The presence of soundproof walls produced a slight noise reduction effect at a distance of 20 m from the track but made no difference to noise levels at distances of 40 m or more in the Figure 10. It is necessary to continuously collect such time-series data to build a meaningful database of noise levels produced by railway projects. Quantitative assessments of key environmental assessment variables will provide the basis for noise-reduction recommendations.

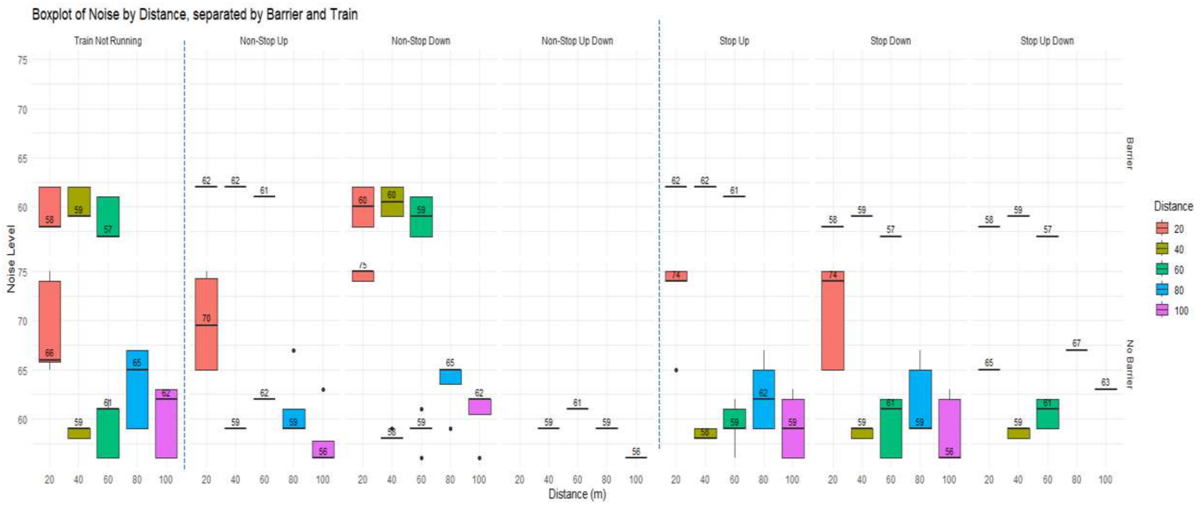

Fig. 10. Analysis of impact by distance according to actual noise.

Scenic value digitalization

Older methods of performing visibility analysis related to the landscape used a combination of digital topographic maps, field photos, and other imagery. Visibility analysis charts were then presented. If the visibility analysis was already built with VR and 3D mapping, less additional analysis should be required, and it should be possible to use the older analysis in conjunction with simulations to understand landscape changes.

Indicators for assessment by landscape type are typically presented qualitatively, so there is a need to review ways to quantify them. Landscape comparisons before and after the construction of artificial facilities should be done, and there is a need to build landscape-level BIMs as well as railway BIMs. We propose the following method of quantifying and digitalizing landscape information. At the project site, measurement sites should be selected and standards established to subdivide and quantify landscape types for environmental landscape information modeling (LIM). Environmental information modeling combines railway BIM with the environmental field, and it refers to the results of 3D modeling that processes 3D digital landscape information acquired by drones and lidar.

Environmental LIM data can be used for landscape evaluation around railway project routes by accommodating landscape type classification and influencing the segmentation and quantification of landscape type (Park, 2022) Drones are useful for acquiring 2D and 3D landscape information, and can be used efficiently in landscape impact assessments because they can compensate for the shortcomings of satellite images and aerial photographs.

After a 3D model of the regional status using drones and lidar has been constructed, a viewpoint based on the 3D model can be selected and visibility analyzed. The step-by-step landscape digitalization plan can be presented as follows. First, during the status survey stage, data from the elements that make up the target space are digitalized for visualization. When predicting the impacts of the project, simulations are performed according to the landscape classification. When proposing an impact mitigation plan, 3D topographical information can then be used to mitigate damage to the terrain and to minimize the sense of shielding and intimidation caused by railroad construction. The 3D topographical information can be used to consider impacts on the surrounding landscape in areas where landscape changes are expected following project route construction. It is proposed that the design be designed to reflect regional and cultural design of the railway route elements in the Figure 11.

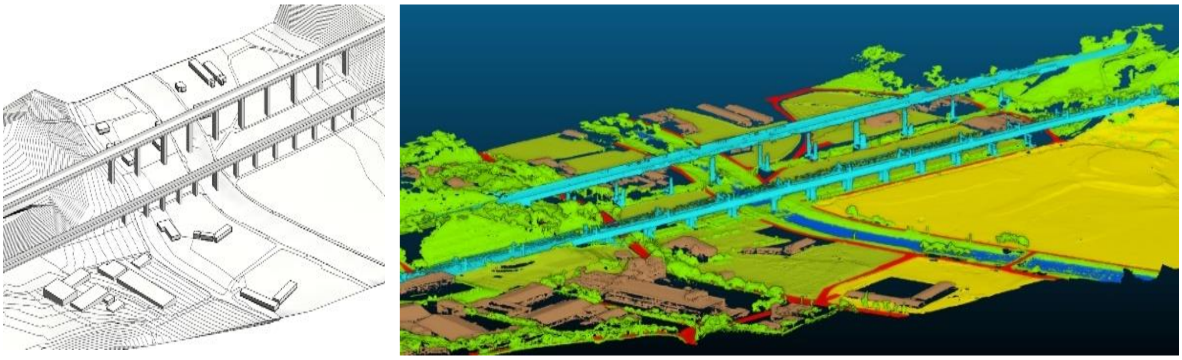

Fig. 11. Semantic segmentation of 3D point cloud data and landscape BIM (LIM) construction.

Conclusion

Drones, lidar, remote sensors, and other technologies of the Fourth Industrial Revolution are being applied in a variety of fields. In this study, we have reviewed the limitations of existing environmental impact assessments of railway projects. We then presented and tested technologies and methods for digitalization of assessments using Fourth Industrial Revolution technologies. When compared with existing satellite maps, high-resolution drone images make it possible to observe landscapes and facilities at high resolution in real time. Depending on camera resolution, it may be possible to secure map data to a precision of 0.5 cm per pixel. In addition, it is possible to create precise survey maps through 3D modeling and 2D orthoimages. These technologies enable assessors to perform real-time analysis by linking them to a variety of applications; they are effective in securing versatility when results are shared in cloud format. In addition, cameras, lidar, and radar can be supplemented with high-definition, drone-mounted image sensors. It is important, however, to evaluate each application according to the characteristics of the variables being measured.

In this study, six key items (air quality, water quality, ecological characteristics, topography, noise and vibration, scenic value) that absolutely required review were targeted from among the available environmental impact assessment items for railway projects. We reviewed the content of existing evaluations and presented what could be derived when applying digitalization methods. In particular, it is necessary to collect time-series data for quantitative evaluation of environmental impact assessments. It is also essential to establish standards for the application of technologies such as drones, lidar, and other sensors.

Publicly available data on air quality had frequently been gathered far from a given target area. We therefore consider it essential to use drones and lidar to collect air-quality field data. It is also necessary to collect data that considers variables such as train speed, train direction, distance from the track, altitude, and the presence or absence of soundproof walls. Microclimatic variables related to air quality must also be reviewed and appropriate data collected. In the case of water quality, it is necessary to review GIS-based gradients through the joint analysis of data collected by drones and USVs together with time-series data on water pollution.

Existing environmental maps, such as the National Natural Environment Survey, are often used to extract ecological data. To enhance the value of ecological items in environmental assessments, it will be necessary to construct realistic digital twins for the area of interest, collect related time-series data using drones, lidar, and infrared cameras, and subsequently to apply quantitative methods to predictive simulations. Across landscapes, it is necessary to classify landscape types using 3D data, and to reproduce the characteristics of each object using landscape BIM simulations. In topographic geology, it is necessary to record time series of topographic changes. When considering the effects of noise, existing noise metrics and low-frequency noise should be quantified, as should the role of these noise categories in creating stress in humans.

In this study, we reviewed in advance the items that needed to be assessed to digitalize existing environmental impact assessments. By securing time-series data using the technologies presented in this study, it will be possible to reduce the manpower, time, and costs of environmental assessments for railway projects. Rational, data-driven decisions can contribute to ensuring the reliability of results derived from environmental impact assessments. Furthermore, the digitalization of all aspects of the environmental infrastructure surrounding the railway will contribute to the eventual establishment of a database for building a digital-twin-based decision-making platform for the railway business. Future research will require the collection of time-series data for more than one year to build a prediction model. The method proposed in this study is limited to railway projects, but its scalability to other transportation construction projects may also be considered in the future.

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Data availability: The data presented in this study are available on request from the corresponding author

Declarations

Ethics approval: Not applicable.

Consent to participate: Not applicable.

Consent for publication: Not applicable.

Ethical responsibilities of authors: As per the instruction for Authors, all authors read, understood, and complied as applicable with the statement on "Ethical responsibilities of Authors."

Competing interests: The authors declare no competing interest

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