Proceedings of the Seventeenth International Conference on
Civil, Structural and Environmental Engineering Computing
Edited by: P. Iványi, J. Kruis and B.H.V. Topping
Civil-Comp Conferences, Volume 6, Paper 15.2
Civil-Comp Press, Edinburgh, United Kingdom, 2023
doi: 10.4203/ccc.6.15.2

High Frequency Monitoring of Winter Road Surface By MPM, and PSS Implementation Using Road Ledger Drawings

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Abstract

In this study, we attempted to incorporate CAD data created in accordance with the Guidelines for the Preparation of Road Construction Completion Drawings into the GIS road surface management DB, which serves as road base map information, via a GIS converter. In addition, we tried to improve the maintenance and management work by linking the results of MPM measurement for understanding road surface properties such as IRI to the pavement management system (PSS), which manages the road ledger CAD/GIS screens, to formulate a repair plan.

Keywords: PSS, MPM, IRI, CAD, GIS convertor

1 Introduction

In accordance with the Basic Act on the Promotion of Utilization of Geospatial Information, which came into effect on August 29, 2007, the making use of road base map information has begun with completed road construction drawings, and the digitization of road-related drawings is underway. Therefore, by creating road base map information (GIS data) using completed road construction drawings (CAD data) created and delivered electronically in accordance with the Manual of Completion Drawing Production for Road Works [1], it is possible to utilize the information in various scenes in road management operations. For example, in pavement management, the large scale of the GIS data can be used to overlay the pavement condition on the road base map information, display color-coded information according to the year, and enhance repair planning by analyzing the priority of repair locations and visualizing repair plans [2]. In this way, by incorporating completed CAD maps used for repair work into the GIS each time, the road base map information can be enhanced and become even more accurate and reliable.

The pavement management systems currently in operation at management agencies have various patterns that require individual customization, so it is fair to say that there is no management system that is highly versatile. The various patterns include, for example, (a) inheritance from the operation systems of past management agencies, (b) linkage with inspection equipment, (c) matching of attributes with management plans, (d) linkage with information such as repair history and IRI, (e) linkage with video, (f) linkage with the budget planning subsystem, (g) linkage with data models (g) linkage with data models, (h) methods of updating information, (i) updating and operation management issues of the database system itself, and (j) additional subsystems to make maintenance planning more efficient.

Local governments, such as municipalities, have not yet developed a versatile pavement management system, partly because they do not have a high financial base. In addition, not many local governments have established their own pavement management systems. Furthermore, CAD data (SFC, etc.) such as as-completion drawings created in accordance with the Guidelines for the Preparation of Road Construction Completion Drawings, etc., are not yet being developed on GIS using converters and utilized in pavement management operations.

In addition, inspections using a road condition survey vehicle are expensive, and frequent inspections are impractical from a cost-effective standpoint. Furthermore, IRI has been measured using a laser, which is not feasible in wet or snowy conditions, which are characteristic of snowy and cold regions.

In previous studies, Nishioka et al. constructed a road infrastructure platform that centrally manages road maintenance and management information based on the use of GIS, realizing real-time updating of accident information and visualization by GIS at low cost [3]. YASUDA et al. linked geometric information (CAD drawings, SXF format) and attribute information (SAF files, XML format) to a database and constructed a system that enables the exchange and linkage of intermediate files via the Web [4]. Fujita et al. have efficiently monitored flatness on urban roads using the MPM (Mobile Profilometer), a simple road surface flatness measuring device using an accelerometer, and have used GIS to understand changes in flatness over time [5].

In this study, as a part of the utilization of road base map information (GIS), a dataset with attribute information (SAF file) added to CAD data (sfc) created in accordance with the Guidelines for the Preparation of Road Construction Completion Maps, etc., was considered to be imported into a GIS via a GIS converter. A case study of Chitose City, Japan, where attributes are added to sfc and the data is deployed in a GIS-based pavement management system via a GIS converter, is presented. The ACTUS system used in this study is an accelerometer-based IRI measurement system that is independent of road surface and weather conditions. By linking the measurement results with the pavement management system, quantitative and continuous data can be accumulated, which will contribute to the improvement of productivity, efficiency and labor saving in pavement management.

2 Features of this study

The advantage of linking MPM to the pavement management system (PSS) described in this paper is the improvement of immediacy in maintenance and management. In pavement management, it is necessary to properly understand the road surface conditions that are constantly changing in order to improve user satisfaction. As an alternative, IRI measurements using MPMs have been implemented, but they are not linked to PSS, and the basic maintenance cycle of inspection, diagnosis, judgment, and action cannot be performed at the necessary time. In addition, to solve the problem of inconsistency between the location information of the road surface measurement vehicle and the location information of the distance marker (KP) used in the PSS, a separate calibration was performed to match the location information at the time of MPM measurement. For this reason, there are few cases where MPM is linked to PSS owned by local governments.

In snowy and cold regions, accidents frequently occur due to frozen road surfaces and snow accumulation during the winter, and road surface condition monitoring must be performed frequently, but road surface condition measuring vehicles cannot meet this demand. This is the advantage of linking MPM to PSS, i.e., immediacy. In snow and ice areas, it has been impossible to measure pavement management indicators such as MCI using lasers, but MPMs such as STAMPER and ACTUS can do so.

Another advantage is that the completed road construction drawings created using the guidelines can be used in PSS for color-coding according to year, analyzing the priority of repair locations, visualizing repair plans, and other advanced repair planning functions. However, local government-owned pavement management systems rarely convert CAD data of as-built drawings to GIS and are not widely used by local governments. This may be due to various reasons, such as the converter not functioning well because the as-built drawings do not conform to the preparation guidelines, or the lack of a function to develop GIS data in PSS. Therefore, advanced repair planning with PSS is far from being achieved.

The flow of data conversion from CAD data to GIS is shown in Figure 1. A dataset with attribute information added to the completed road construction drawings (CAD data, SFC format) created and delivered electronically in accordance with the Guidelines for the Preparation of Completed Road Construction Drawings is converted, and new CAD information (P21 and SAF) is created. This CAD information is converted to GIS information using the GIS Converter (CAD-GIS Converter [Road Version] Ver. 2.4) published by the National Institute for Land and Infrastructure Management (NILIM), and then imported into PSS to complete the data conversion process. The "Support Site for Creating Completed Road Construction Maps, etc. "[6] is available on the website of the National Institute for Land and Infrastructure Management (NILIM). In addition, the "Check Program for Completed

Road Construction Drawings Ver. 3.3 (as of 2020.05.15)," a tool for checking whether data conversion is functioning properly, is also available for download.

The reason for using plan drawings as the basis of PSS is that plan drawings are most frequently used in maintenance and management work. A questionnaire survey [7] of the management organizations shows that the plan view is the most frequently used drawing type (plan view, general view, structural view, cross-sectional view, and longitudinal sectional view) for maintenance and management purposes. The fact that about half of the organizations (43%) use plan drawings in total makes it extremely logical to link attribute information to frequently used plan drawings in maintenance management work.

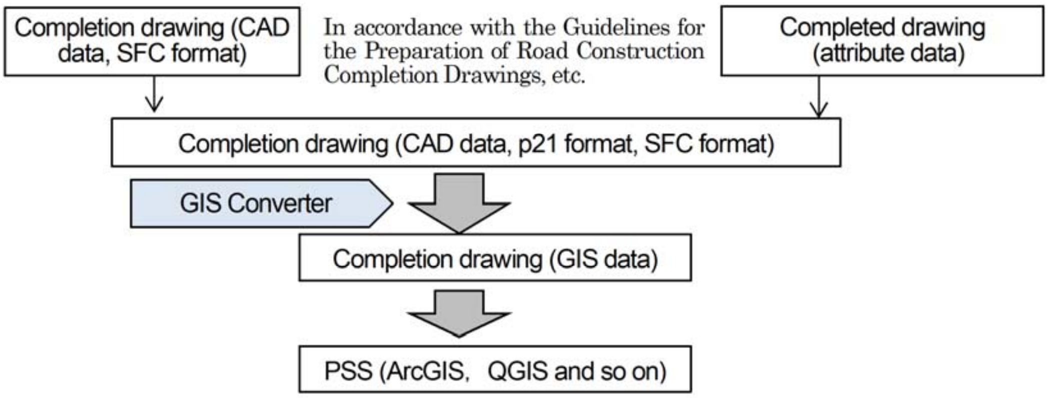

Figure 1: The flow of data conversion from CAD data to GIS.

3 Structure of Pavement Support System

3.1 PSS Outline

In addition to the GIS road surface management DB that links the CAD/GIS screen of the road register with moving images, seamless road surface management is possible by linking the acceleration data acquired by ACTUS with IRI and KP-compatible pavement health graphs. Figure 2 shows the structure of the GIS road surface management database.

As shown in the upper left of Figure 2, the GIS road surface management database PSS has information such as route name, inspection date, starting and ending points of city roads, and measurement points, and can also extract inspection history such as MCI and IRI, pavement type, and pavement ID numbers with damage greater than threshold values on a map. In addition, the system automatically identifies areas to be repaired when the MCI, IRI, or other standard values are changed. Project costs can be calculated based on repair methods and unit costs. The progress of deterioration of each roadway can be monitored, and a five-year plan for pavement repair can be formulated, enabling appropriate project execution within a limited budget.

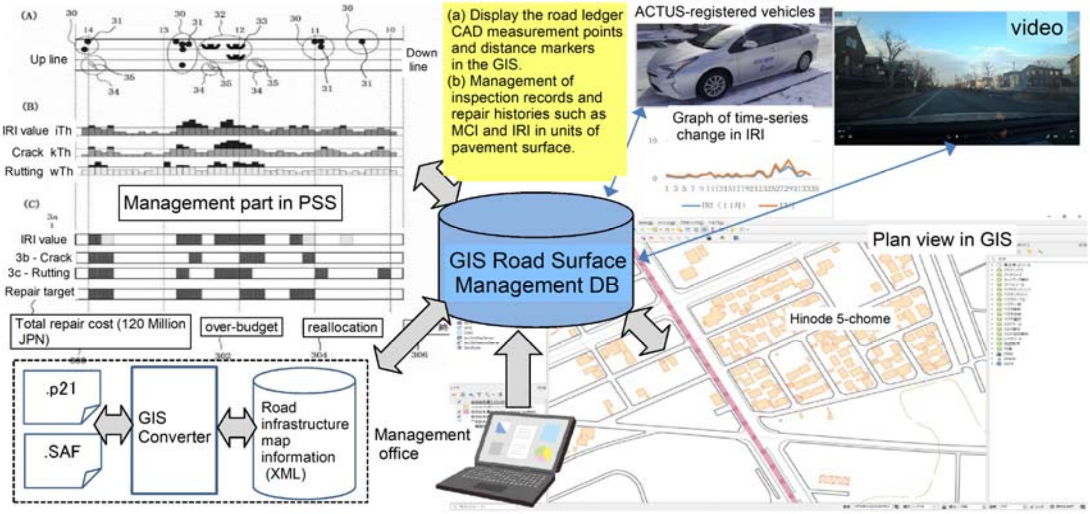

Figure 2: GIS Road Surface Management Database Configuration.

3.2 MPM Outline

MPM is a device to measure the International Roughness Index Flatness (hereinafter abbreviated as IRI). Two accelerometers and a GPS antenna (GNSS) are installed above and below the front wheels of the vehicle (Prius) on one side to calculate IRI from road surface displacement, time, speed and distance. The accelerometers and the main unit are connected wirelessly, so installation is easy and compact, and the system can be installed in large, small, and light vehicles without limitations. In addition, to improve the accuracy of the location information, this research uses vehicle speed pulses to calculate the cumulative distance.
The IRI data interval can be selected between 10m and 100m. A grip switch is also included, which can be pressed to record the data on the GPS. The MPM measurement screen is shown in Figure 3.

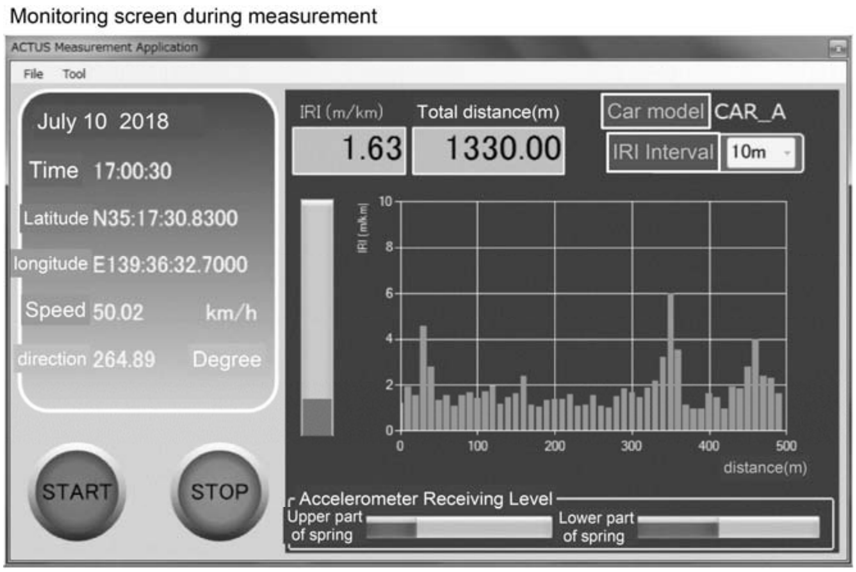

Figure 3: ACTUS Measurement Screenshot.

3.3 Output from PSS database

The output image of the PSS database is shown in Figure 4. The database functions include histogram display of IRI and RMS values, route plan display, display of sections above a set threshold, data superimposition function, and repair cost simulation function. Since the plan view is the most frequently used for management purposes, the superimposition of various information on this plan view enables more sophisticated use of the repair plan. For example, a schematic diagram of the route with kilometerposts displayed with the distance on the horizontal axis, a graphical display with IRI and RMS superimposed, for example, a threshold IRI value of 2 or more and a section above the threshold value can be displayed in a different color on the plan view, and the repair cost calculated by multiplying the section extension below the threshold value by the unit repair cost can be displayed as the section to be repaired to indicate whether the budget set by the user exceeds the repair cost or not. If the budget is exceeded, the threshold value can be changed for simulation purposes.

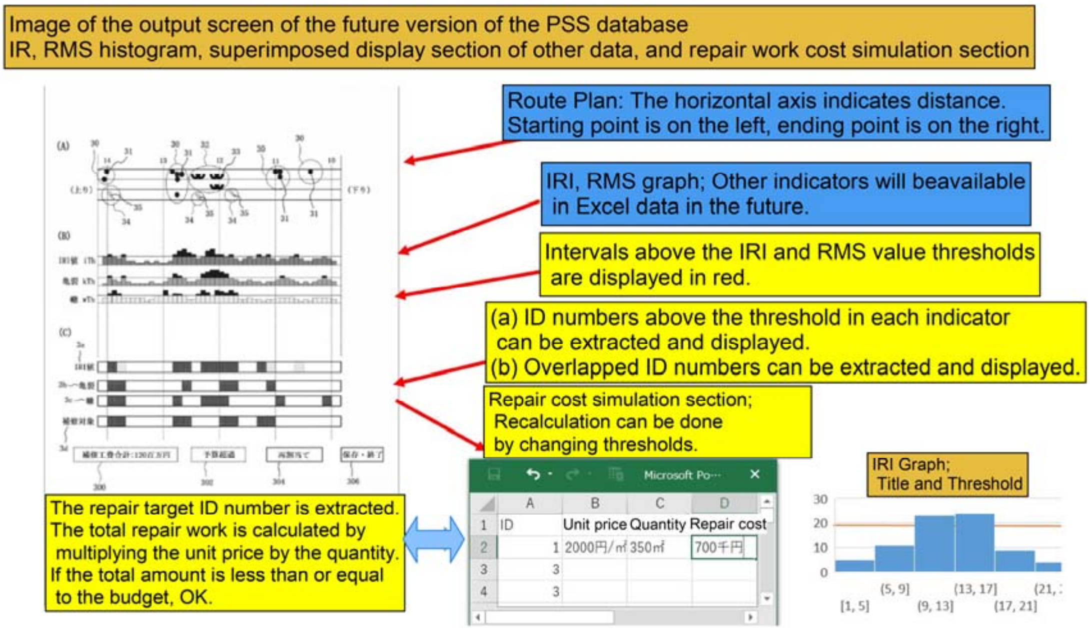

Figure 4: Image of PSS database output screen.

4 Construction of Pavement Support System

The PSS is divided into two parts: (1) DB and (2) GIS, where the DB is mainly responsible for retrieving and storing road surface management data and the GIS is responsible for displaying maps. These data are accumulated from daily inspections, emergency inspections, complaints received, and other processes. On the other hand, the GIS assists in supporting repair planning and budget planning as an indication of the pavement surface.

4.1 Database

The DB can perform (1) measurement data capture and (2) measurement data selection processing. Data processing includes time-series deterioration transition graphs for each route, deterioration repair location graphs, and data aggregation by route.

4.2 Visualization display section (GIS ledger)

Based on the city-owned road ledger CAD drawings, the completed drawings of the sections that have been repaired or reconstructed are imported into the road ledger via the GIS converter described in Chapter 3. This allows road surface condition data measured at any given date and time to be immediately reflected, and the latest road conditions can be monitored in the management system. The GIS-based system can display wide-area maps and detailed maps freely. In addition, the pavement surface (polygon) of each route can be displayed, and the road surface condition data can be ranked and colored for visualization.

Figure 5 shows an example of the GIS display screen in PSS.

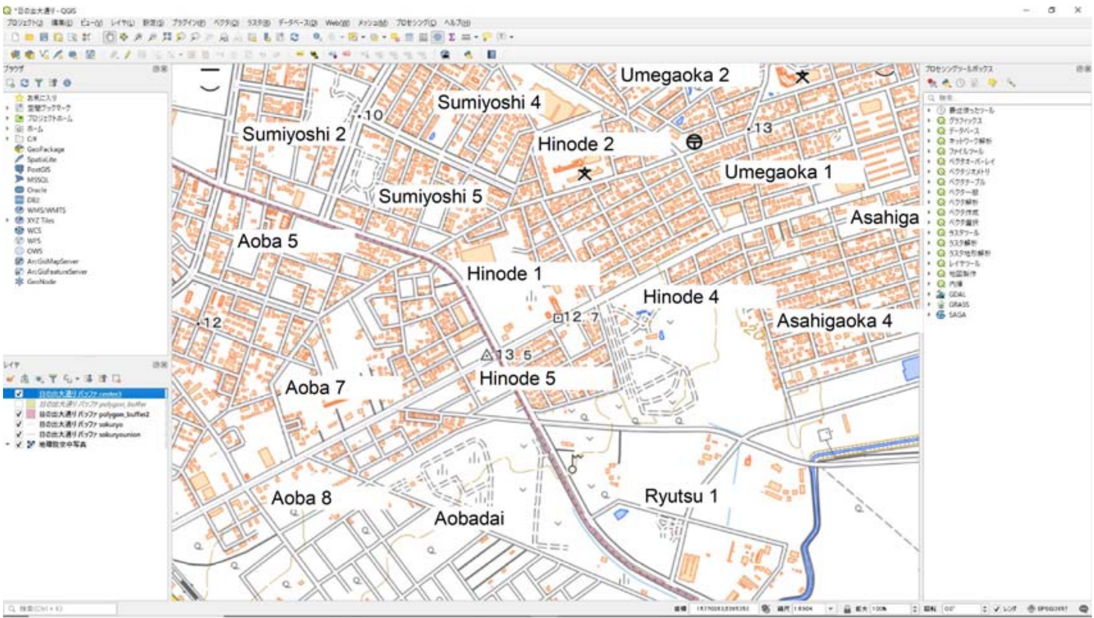

Figure 5: An example of the GIS display screen in PSS.

4.3 Efforts toward 3D

It is thought that a pseudo-3D structure of a pavement can be realized by adding attribute information (surface and base layer thickness, roadbed heat, and roadbed height) in the height (depth) direction to the 2D information (geometric information plan view, attribute information). After confirming that this method can be loaded and displayed with commercially available 3D-CAD software, a 3D model of the pavement can be easily constructed by modeling with JHDM [8] using the PSS constructed in this study. JHDM means Japan Highway Data Model. The method by

JHDM can be realized by integrating the attribute (construction record record record) cross-sectional information with the basic pavement information (geographic information standard, etc.).

Figure 6 shows how JHDM can be linked to the database. The road structure model in JHDM can be implemented in the database by directly matching it to the tables in the database.

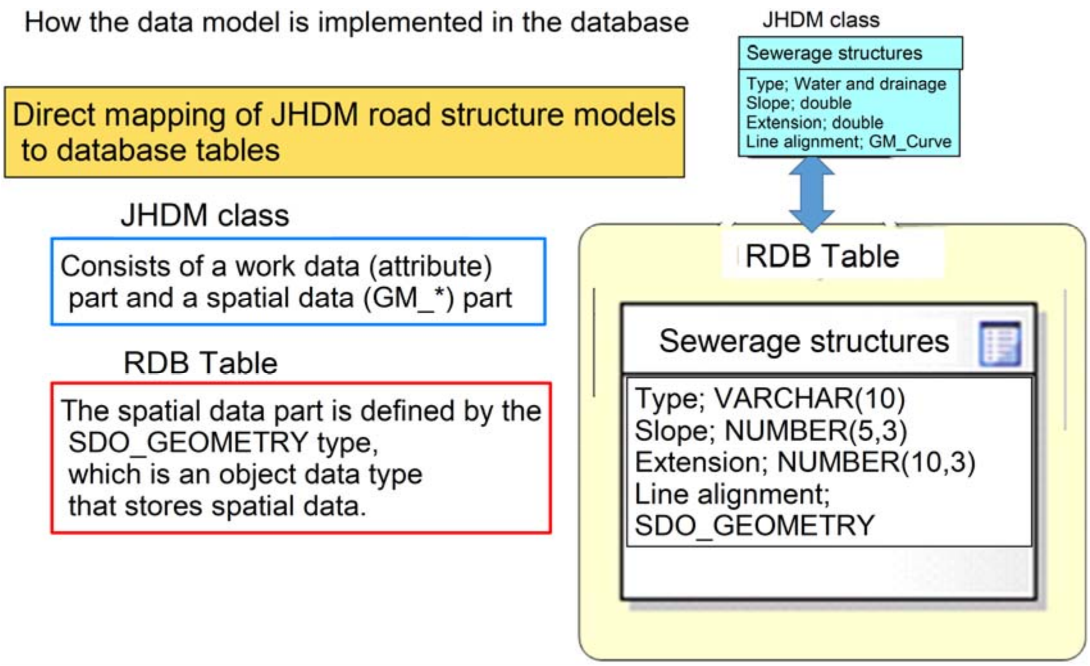

Figure 6: How to link JHDM with databases

5 Conclusions and Contributions

In this study, we attempted to incorporate CAD data created in accordance with the Guidelines for the Preparation of Road Construction Completion Drawings into the GIS road surface management database, which serves as road base map information, via a GIS converter. The Pavement Stabilization System (PSS), which manages the CAD/GIS screen of the road register, is linked to the MPM measurement results for understanding road surface properties such as IRI to enhance maintenance and management operations such as the formulation of repair plans.

The conclusions of this study are as follows.By importing CAD data created in accordance with the Guidelines for the Preparation of Completed Road Construction Drawings into the GIS road surface management DB, various maintenance management functions, such as superimposition of pavement conditions and analysis of priorities for repair locations, can be used.

Future issues are that most road plans use geodetic coordinates, which must be converted to latitude and longitude in order to be displayed in GIS. In terms of drawing file format, road administrators and local governments do not have a unified format, so it is necessary to be able to handle a variety of file formats. In addition, we would like to develop a method to predict the rate of pavement deterioration in cold regions, to support the estimation of pavement repair costs, and to evaluate road surfaces using new indices.

Acknowledgements

The construction of the pavement management system (GIS) including MCI in this study was made possible with the cooperation of the Chitose City Construction Department, and we would like to express our gratitude to them.

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