論　文　の　要　旨

題目　Research on development of road engineering automated index detection equipment importing the circular economy strategies

（循環経済戦略を取り入れた道路工学自動指標検出装置の開発に関する研究）

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The purpose of this research is to find out the best strategic planning model for the overall paving project. Through artificial intelligence and methodologies, we can find destroyed asphalt pavement of the road more quickly, know the best construction site to maintain, and cut down the completion day then to save energy and reduce carbon emissions. The development of the real-time road patrol management system and lean management system can accelerate administrative efficiency and field management and reduce the waste of manpower, machines, and equipment, which makes the overall research strategy more efficient. Furthermore, it not only improves the efficiency of the overall project but also reduces the effects on the environment and environmental costs, which creates a win-win situation.

The research mainly cooperates with the application of recycling economy materials such as incineration renewable aggregates, electric arc furnace slags, and recycle aggregates into road engineering and the application of new materials and methods for road engineering. The applications are promoted by the Environmental Protection Agency of the Taiwan Executive Yuan, the Taoyuan City Government, the Freeway Bureau, and the Directorate General of Highways.

This thesis is divided into nine chapters, and the detailed organization of the thesis is described as follows:

Chapter 1 presents the background, purposes, and methodology of this study.

Chapter 2 describes literature review related to this thesis.

Chapter 3 presents the reduction of the impact of carbon emissions associated with the transport of materials in highway pavement construction projects. A sparse-coding support-vector methodology is employed to analyze four major indices of highway pavement: the international roughness index (IRI), structural number (SN), pavement condition index (PCI), and equivalent single-axle loads (ESALs). The energy-conservation and carbon-reduction efforts of construction vendors are also evaluated. The proposed model can be further generalized by employing a wider range of traffic data, additional roughness indices, and structural properties of pavement. An optimization scheme is formulated as a mixed-integer linear programming problem based on the time required for asphalt inspection using spatial networks and operating constraints.

Chapter 4 provides the addition of energy conservation and carbon reduction into precasting concrete plant to improve the level of quality further. Application of the cost efficiency with the introduction of carbon calculator for the “carbon footprint” and lowering carbon emission strategies is further discussed. During the life cycle of precasting structure, a good structure design incorporates not only the planning and design, but also its materials, equipment, and construction, which make up the important elements in preparing the final products in the precasting concrete plant.

Chapter 5 discusses the effects of frequent road inspections that are key to maintaining road quality and avoiding casualties associated with poor road conditions. In Taiwan, open contractors conduct inspections of roads

and ancillary facilities daily or weekly according to the requirements of the agency awarding the contracts. Unfortunately, the equipment used for inspecting the inspection data lacks follow-up applications and numerical conversions, such as the Pavement Condition Index (PCI), to compile a large-scale database to facilitate the long-term conservation of roads. This study developed back-end image recognition software using existing road inspection methods and equipment. This was aimed at enhancing inspection efficiency by enabling the automatic identification of road damage. Resulting observations can then be converted into PCI values in accordance with ASTM D6433-16 to be exported as a numeric value indicative of road quality. A vehicle-mounted traffic recorder and imaging device with Wi-Fi transmission capability are used as hardware, and the relationship between the captured images and the speed of the car is used to obtain an accurate indication of road conditions across the surface. The SLIC Superpixels algorithm (using two stages of image grouping) is used to identify areas with pavement damage as patches, potholes, longitudinal cracking, and crocodile cracking. The results of the proposed fully-automated method conform strongly with those obtained using semi-automated pavement inspection software. Despite the restrictions imposed by the limited depth measurement of 2D images, our method achieved results close to those obtained using manual inspection. Future developments will include the application of artificial intelligence to enhance the effectiveness of this software.

Chapter 6 examines the theoretical and analytical solutions concerning the industrial layout and vendor location of Taiwanese asphalt vendors by adopting the industrial location theory. The analysis was divided into a macro-analysis and a micro-analysis. The macro-analysis analyzed sectional and national industrial layout. The micro-analysis examined vendor choice theory. The analyses were based on the locations of the vendors along different national freeway sections. The outcomes were used to propose transport and labor location principals for the various sections. Finally, equal-cost charts were illustrated for the different sections to determine the optimal vendor location.

Chapter 7 estimates pavement performance indicators (i.e., the IRI, ESALs, SN, and PCI) employing the SCSV method. Each parameter was entered one by one and brought together using seven different models. This resulted in a predictably high success rate to the value of the IRI. Many highway agencies have the equipment necessary to take IRI readings but are unable to afford the personnel that such readings require. The proposed model allows the state of pavement to be estimated at present and in the near future in assisting scheduling maintenance projects. The proposed scheme is designed to minimize CO_2 emissions for a set quantity of repair materials. Likewise, the proposed scheme can be used to extend the length of road that could be repaired for a given amount of CO_2 emissions. Decision-makers can determine whether to enhance the efficiency of road work or to lower CO_2 emissions according to the results of the analysis. The proposed model could be generalized to a wider range of situations by including a wider range of traffic data, pavement structural properties, and roughness indices.

Chapter 8 states the conclusions of the thesis. This research can analyze pavement index and evaluate energy-saving and carbon reduction through sparse-coding support-vector's optimization analysis, then find a single work area that will reduce CO_2 emissions by approximately 11-28%. The result in inspecting Taiwan 31th Provincial Road could match 85.7% with the contractor inspection which means the result is similar to the existing pavement inspection method. The application of road image automatic identification system software and hardware developed through AI intelligent deep learning can save 500-800 million dollars of the government's annual budget. Through a lean management system, we can cut down completion day and reduce the budget, which makes the process more efficient and save a lot of money.