Building Information Modelling - Asset Management - Railway Safety (BIM-AM-RS) to Enhance Railway Safety in Hong Kong

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Abstract: Building Information Modelling (BIM) is getting popular in major railway construction projects. Its usage during its operation stage is typically pursued as an inventory-type asset management tool, namely BIM-AM. This paper outlines the extended usage of BIM-AM to a new platform, which we call "BIM-AM- Railway Safety" (or BIM-AM-RS), to provide enhanced training to operation and maintenance (O&M) staff and to support carrying out predictive maintenance for railway assets by (a) utilizing its 3D visualization capability of the railway assets with adoption of virtual reality and haptic technology; and (b) applying artificial intelligence (AI) and data analytic technologies to digest and make good use of large volume of real time data collected from railway assets. With the expanding railway network, increasing number of patronage leading to a heavily loaded railway system, and railways facilities reaching their replacement ages, it is necessary to develop an innovative system to enhance railway safety and overall system reliability.

Keywords: Building Information Modelling; asset management; railway safety; predictive maintenance; artificial intelligence; data analytics; haptic technology

1. Introduction

The Electrical and Mechanical Services Department (EMSD) is the authority in Hong Kong regulating railway safety of the railway operator MTR Corporation Limited (MTRCL), which operates metro, light rail, and intercity high speed rail in Hong Kong. The major functions of EMSD regarding railway safety are ensuring the adoption of appropriate safety measures by MTRCL to assure safe operations of its railway systems; assessing and vetting new railway projects and major modifications of existing railway facilities; assessing and following up with MTRCL on improvement measures in respect of railway safety; and investigating safety-related railway incidents and recommending improvement measures to prevent recurrence of the incidents.

In recent years, BIM, which is a digital model and process supporting the representation of building elements in terms of their geometric and functional attributes as well as their inter-object relationships, has rapidly emerged in architecture, engineering and construction industry to facilitate effective and efficient coordination among different disciplines, leading to significant shrink of construction schedules and project costs. To support the use of BIM, projects for new railway lines in Hong Kong (e.g. Shatin to Central Link) will also adopt BIM technology in design and construction stages. Whilst BIM is getting more popular in construction projects, its usage during its operation stage is typically pursued as an inventory-type asset management tool, namely BIM-AM. BIM-AM enables intuitive cross-reference among BIM models, asset attributes, maintenance history, asset relationships, manuals and schematic drawings.

With increasing expectation of passengers on high quality railway services and growing railway network (e.g. new lines / extensions) today, the traditional maintenance regime for railway safety has to be further enhanced in an innovative way. By reference to the experiences of other overseas railway operators, the application of innovative technologies for carrying out predictive maintenance and real time monitoring of railway assets has been successful to enhance railway safety and reliability. This paper outlines the extended usage of BIM-AM to a new platform called BIM-AM-RS to support predictive maintenance for railway assets and provide enhanced training to O&M staff.

2. Background

The BIM-AM-RS aims at (i) improving railway safety and reducing incidents via implementation of predictive maintenance for railway facilities and (ii) enhancing staff competence via 3D BIM interactive training with haptic technology. It is not aware in the industry any integration of BIM-AM with real time operating conditions of major railway assets to support their predictive maintenance. By taking up the role of "facilitator" following the government policy since 2018, EMSD explores the possibilities of adopting new technologies by railway operators. This new BIM-AM-RS platform initiated by EMSD is now being developed by MTRCL in the areas on enhanced training and application of new technologies to support predictive maintenance for major railway assets.

Enhanced Training: The BIM-AM-RS aims to develop a training kit providing enhanced training to the O&M staff of MTRCL. A prototype of the training kit has been developed by adopting Virtual Reality (VR) and haptic technology in early 2019. Scenarios of some past electrical incidents have been developed under the BIM-AM-RS environment simulating the incident site environment. The training kit could assist O&M staff to experience the consequence and haptic feedbacks of NOT following the correct O&M procedures via the haptic suit and helmet worn by the staff during the training. Figure 1 depicts the framework for enhanced training of BIM-AM-RS platform.

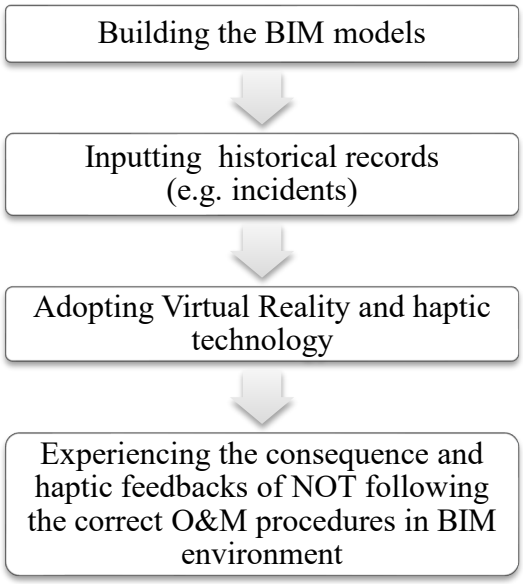

Figure 1: The framework for Enhanced Training of BIM-AM-RS platform

On the aspect of predictive maintenance, a BIM-AM-RS platform is being created to visualize the results of AI data analytics of historical and real time data of major railway assets. Health conditions of major railway assets would be visualized on-line through the platform to provide the necessary trend analysis, health indices, etc., which form the basis of railway asset predictive maintenance system. Figure 2 depicts the framework for predictive maintenance of BIM-AM-RS platform.

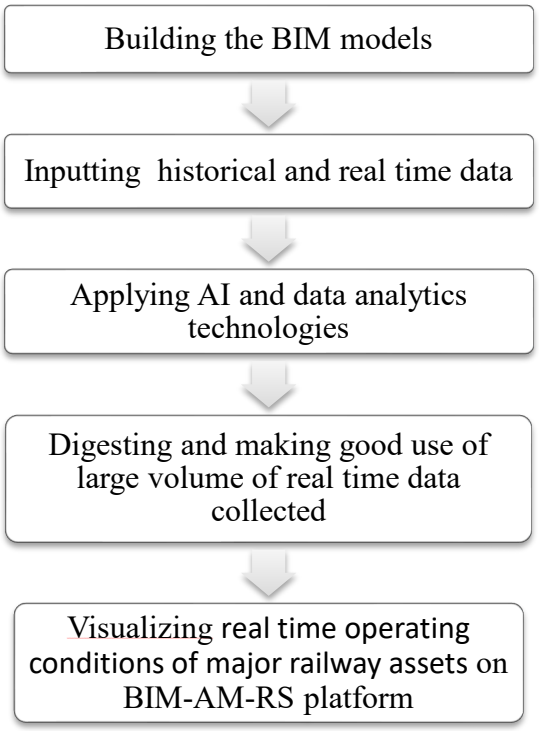

Figure 2: The framework for Predictive Maintenance of BIM-AM-RS platform

3. Enhanced training

The BIM-AM-RS platform enables intuitive cross-reference among BIM model, asset attributes, historical records (e.g. maintenance and incident records), manuals and schematic drawings at a single terminal. Historical records, especially those related to railway incidents, fed into this new BIM-AM-RS platform can also be used for enhanced training of O&M staff to minimize human-factor related incidents. As the maintenance window of railway systems in Hong Kong is in general very short (around 2 hours in mid-night every day), it is difficult to arrange frequent on-site training to O&M staff. As such, the training kit developed with BIM-AM-RS would enable O&M staff to practise O&M procedures in office, workshop, classroom or any other work sites. Figures 3(a), (b) and (c) show that the VR training with haptic technology can be performed in workshop environment.

Figure 3(a)

Figure 3(b)

Figure 3(c)

Figures 3(a), (b) and (c): VR training with haptic technology in workshop environment

With a view to promoting training enhancement with BIM-AM-RS in the trade, 5 prototype of training modules were developed by EMSD to simulate the environment of some past railway incidents occurred in metro lines, high speed rail and automatic people mover in airport. These training modules together with haptic suits were on loan to MTRCL for use and further development of its own training modules. To illustrate the workflow of developing the training module, an incident about operation of an isolator under on-load condition is taken as an example. As the first step, the BIM models for major railway assets (e.g. pantograph, overhead line, isolator and earth rod) in relation to the incident were built. Figures 4 (a) and (b) depict the BIM models of the pantograph and isolator involved in the incident case.

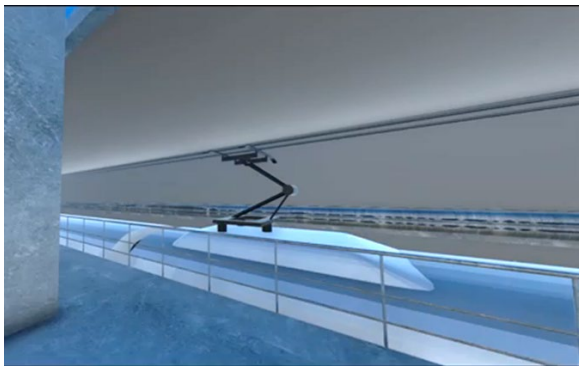

Figure 4(a)

Figure 4(b)

Figures 4(a) and (b): BIM models of the pantograph and isolator in the incident case

The O&M procedures relating to the incident were then reconstructed as a sequence of 3D interactive scenes in the VR environment. The 3D interactive scenes and associated haptic feedback resembling electric shock and explosion were developed. To enable higher flexibility of the training venue, the training kit has been developed for the platforms of Cave Automated Virtual Environment (CAVE) and VR helmet. The management of MTRCL training unit fully agreed with the direction on development of BIM-AM-RS for enhanced training and believed that these haptic feedbacks including vibrations, which resemble electric shock, explosion, etc., coupled with the visual and sensing effects under the BIM environment would leave a deep impression of the staff on the consequence of wrong doings. The training modules prepared by EMSD have been incorporated in MTRCL's training starting from June 2019. The target audience is mainly new recruited staff who have no previous exposure to railway operation site environment, as well as experienced operation staff for refreshing their knowledge and acquiring new qualifications.

Figure 5: Staff training in CAVE

Currently, MTRCL is developing 5 new scenarios for VR training in handling of depot shunting and working at height with target to complete by end of 2019. These new scenarios will also adopt haptic feedback features to deepen the staff's awareness of the consequence of wrong doings.

4. Predictive maintenance

BIM-AM-RS also aims to facilitate proactive asset management through carrying out predictive maintenance for major railway assets. To achieve this objective, the health conditions of major railway assets (i.e. permanent way, signalling system, rolling stock, power supply system and railway station equipment) would be monitored by different Internet-of-Things (IoT) sensors. Various IoT technologies would be applied to measure the real time operational parameters of major railway assets. Current projects for MTR network include stray current corrosion monitoring, partial discharge for switchgear monitoring, optical camera for rail crack monitoring, thermal and optical image for pantograph monitoring, catenary monitoring, turnout / railway switch monitoring, dissolved gas analysis for transformer monitoring, image recognition to detect external objects for escalator protection and data modelling for escalator health conditions monitoring. The incorporation of these technologies in BIM-AM-RS platform for predictive maintenance of railway assets has the benefit to allow real time visualisation of the asset conditions and swift identification of problem location(s) by the operator within an integrated single platform.

The BIM-AM-RS platform would comprise several major components: (i) input of historical data; (ii) field sensors/equipment installation and interfacing; (iii) artificial intelligence (AI) engine for analysis of historical and real time data; (iv) network equipment and computer server for data communication and machine learning; and (v) visualisation of asset conditions for evaluation of health indices to support implementation of predictive maintenance. Figure 6 shows the implementation framework of BIM-AM-RS in railway system.

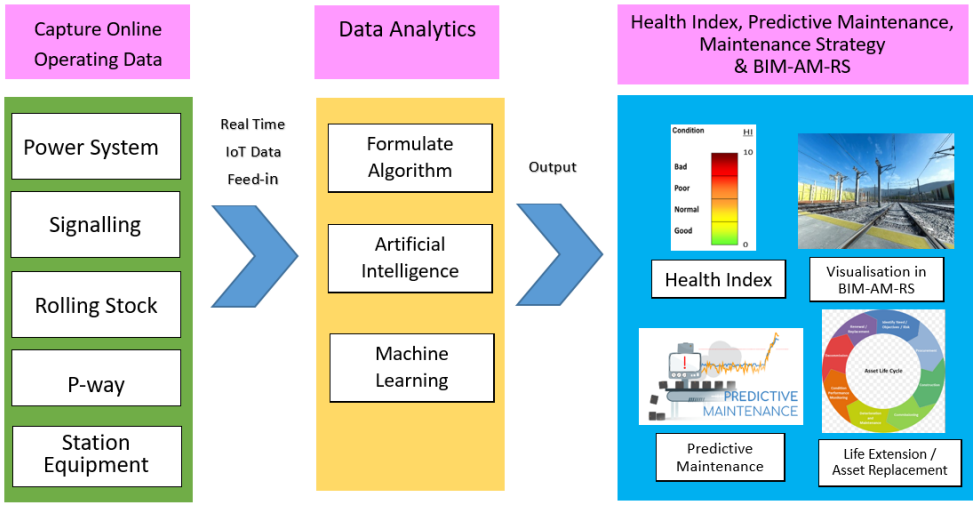

Figure 6: Implementation framework of BIM-AM-RS

Upon the completion of developing the BIM-AM-RS platform, with massive amount of IoT sensors to be installed or embedded in the railway assets, AI and other data analytics technologies would be applied to digest and make use of the big data including historical maintenance and incident records, and real time data collected from major railway assets. The results of the AI and data analytics would be visualized online through the BIM-AM-RS platform to provide the necessary health indices, trend analysis, early warning and actionable recommendations, which form the basis of railway asset predictive maintenance system. Figures 7(a) to (e) show the monitoring of real time operating conditions of railway assets, e.g.

stray current monitoring, pantograph monitoring, catenary monitoring, small and bulky objects detection in escalator, through the BIM-AM-RS platform.

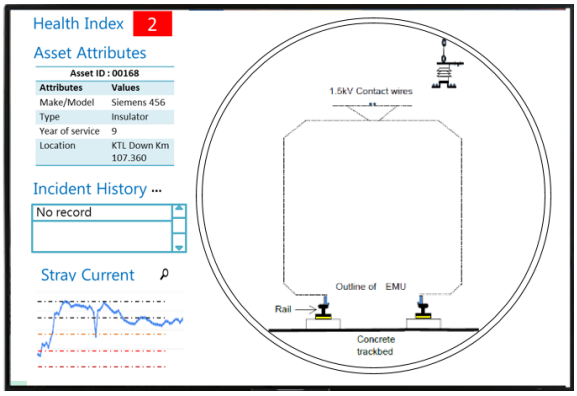

Figure 7(a): Stray Current Monitoring

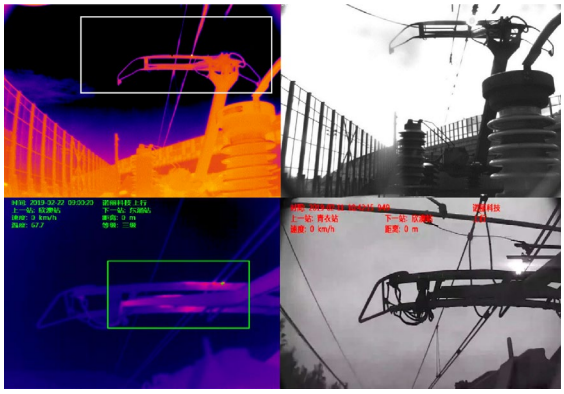

Figure 7(b): Pantograph Monitoring

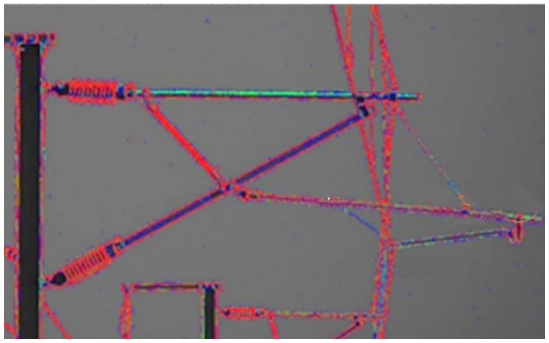

Figure 7(c): Catenary Monitoring

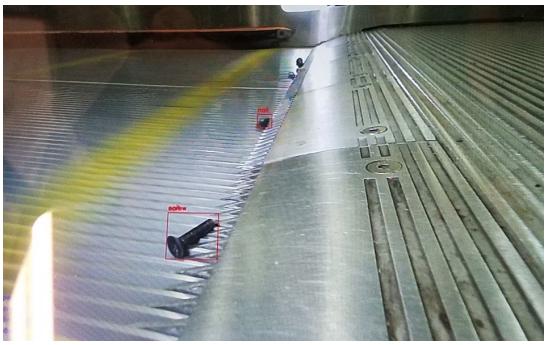

Figure 7(d): Detection of small objects in escalator

Figure 7(e): Detection of bulky objects in escalator

5. E&M InnoPortal

In recent years, EMSD has been fostering collaboration with the trade to develop Innovation and Technology (I&T) solutions for government departments. EMSD has launched the "E&M InnoPortal" which is a platform for I&T collaboration and maintains a list of technology development needs of various government departments, public bodies and the E&M trade since 2018. 12 railway safety related items asking for use of new technologies to enhance railway safety have been put on the platform for matching technical solutions from universities and

start-ups. In addition, EMSD has signed a memorandum of co-operation with five local universities and seven research institutions in June 2019 (Figure 8) so as to establish a strategic partnership to support the application of I&T in government departments for improving their services delivery and enhancing work efficiency. The abovementioned universities and research institutions will become I&T strategic partners of EMSD and will explore and develop technical solutions to address the I&T needs registered in the E&M InnoPortal.

Figure 8: Signing ceremony of the Memorandum of Co-operation between EMSD and partners research institutions

6. Conclusion and Way Forward

The BIM-AM-RS showcases the adoption of new technologies for enhancing railway safety in Hong Kong. It extends the usage of BIM-AM to enable predictive maintenance of railway assets and providing enhanced training to O&M staff. The BIM-AM-RS platform utilizes its strength of 3D visualization capability of the railway assets and prompt retrieval of asset operation and maintenance information. The platform, with incorporation of IoT, AI and data analytic technologies, would digest and make good use of large volume of real time data collected from railway assets to assist the management team for decision making in formulating appropriate maintenance strategies. With the advancement of AI technologies in future, more effective and efficient predictive maintenance could be achieved. Through the platform of BIM-AM-RS, we would expect that both human-factor related and equipment failure related incidents in railway would be greatly reduced in the future.

EMSD will continue to closely coordinate with MTRCL and facilitate it to develop the BIM-AM-RS platform. Reference to the best practices and experience exchange with railway operators and regulators worldwide will be made for developing the BIM-AM-RS platform to further enhance railway safety in Hong Kong.