GIS-Based Remote Monitoring System for Traffic Lights, Footbridge Lifts and Escalators in Hong Kong

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Abstract

The Electrical and Mechanical Services Department (EMSD) of the Hong Kong Special Administration Region Government (HKSARG) has recently implemented a Geographic Information System (GIS)-Based Remote Monitoring System. The objective of the System is to support the operation and monitoring of field equipment for traffic and pedestrian flow control. The System has facilitated the management of equipment life cycle, refining EMSD's overall asset management initiative. It allows information flow and remote access across all levels of staff members that are in charge within EMSD. The System also offers timely visualisation of asset conditions, fault histories, and current status. This monitoring tool is especially useful upon breakdown of field equipment when prompt corrective maintenance may be required. The System has contributed significantly towards the safe, reliable, effective and efficient operation of traffic control equipment and footbridge lifts and escalators in Hong Kong.

Keywords

Traffic Control System, Geographic Information System, Remote Monitoring, Traffic Lights, Lifts, Escalators

1. INTRODUCTION

Hong Kong is a densely populated city with some of the world's busiest road traffic. Continuous development and rapid economic growth has contributed to the growth of transportation load. In order to maximise road capacity and to expedite pedestrian flow, area traffic control (ATC) systems covering 1,800 signalised junctions operate round-the-clock in association with lifts and escalators that are installed at some 300 footbridges for the safety and convenience of pedestrians.

In addition to the implementation of life cycle management measures laid down in the Publicly Available Specification (PAS) 55 for maintenance of traffic signal system in Hong Kong [LEE et al, 2014], a GIS-based Remote Monitoring System (the System) was developed and employed for easier monitoring and maintenance of traffic control equipment (or collectively referred to as asset).

2. MAINTENANCE OF EQUIPMENT

2.1 Requirement

To provide a safe and an efficient traffic environment for vehicles and pedestrians, signalised traffic lights are widely used in Hong Kong. As these traffic control field equipment and systems are necessary for providing round-the-clock operation, any scheduled or unscheduled service outages would pose inconvenience to the public or even threats to safety. Traffic control field equipment as well as footbridge lift and escalator systems are essential, and thus require careful attention.

2.2 Challenges

There are currently 3 separate dedicated ATC systems operating in Hong Kong; each of which being supported by different unique original contractor. Although a lot of field equipment is installed with controllers capable of reporting equipment status back to one of the three distinctly located ATC central servers, updated information is kept separately in various proprietary formats, due to the presence of a mix of ATC systems.

As a result, a high licensing and development cost may be incurred for collecting updated status of remote equipment from the ATC servers directly through the respective application programming interfaces (API). Fault records of field equipment are only reported by maintenance contractors on a bi-weekly or monthly basis. The records are then kept in their particular formats and stored separately by the different contractors. The difference in record formats has caused difficulties in forming a holistic view of the overall asset condition by EMSD for analysis purpose.

As the information on asset conditions and the respective fault histories are considered as sensitive data by asset owners, it should not be exposed to any third party or external cloud-based solution providers (e.g. Bing Map, Google Map, etc.).

In this regard, EMSD has to implement the GIS-based Remote Monitoring System as an internal system with the following major objectives:-

(a) to serve as a centralised information hub providing consolidated views of relevant asset information, asset conditions, and asset healthiness that can be collected from different ATC systems and other applicable data sources,

(b) to provide a unified platform for different levels of staff members to obtain and to analyse related asset information and asset conditions, and

(c) to offer a cost effective solution for consolidating and displaying updated (or close-to-real time) asset healthiness of the equipment.

3. THE GIS-BASED REMOTE MONITORING SYSTEM

Striving towards continuous quality improvement in asset management strategy in EMSD, the GIS-based Remote Monitoring System was developed internally and implemented in late 2014 to support the maintenance of Traffic Lights, Footbridge Lifts and Escalators in Hong Kong.

3.1 Data Source

The Remote Monitoring System was developed and implemented in two phases. Phase I of the System has a focus on the provision of a GIS-based display of asset information and tools for analysing fault records collected from maintenance contractors; whereas Phase II has a focus on the collection and display of updated asset status collected directly from the source ATC systems.

Base maps from the Lands Department of the Hong Kong Special Administration Region Government (HKSARG) are used for the underlying map display.

Location information of the assets was converted from textual representation to marks on the base maps. Asset information and their respective fault records were imported from an existing Asset Management (AM) database, which is built to support the EMSD ISO 55001 Asset Management System. By combing these datasets, the Remote-Monitoring System could be built in a very short time, while providing easy access to the asset information.

Datasets for Phase II of the Remote Monitoring System are collected from the 3 separated ATC systems through dedicated virtual private network (VPN) connections. Updated asset details such as fault code and asset ID are obtained from the ATC system log files and replicated to a central log server in the EMSD Headquarters for further processing, before the information is made available through the Remote Monitoring System. Data adapters are used to convert the system log files from their proprietary format to a standardised one for usage in the Remote Monitoring System.

Although the ATC systems provide APIs for obtaining updated equipment status in the ATC servers, the license for the APIs is rather costly for remote monitoring purpose. The use of the ATC log files, in which API license is not required, can cost-effectively provide all essential information that is required for the remote monitoring and analysis purpose.

Under this arrangement, updated status of field equipment can be acquired from concerned ATC systems; and the maintenance teams are notified immediately of any potential service outage, enabling remedial actions to be taken promptly and hence improving maintenance efficiency.

3.2 Design

The System adopts a web-based user interface and is designed to support up to 200 concurrent accesses through EMSD's internal network. An overview of the System diagram for the Phase I and II implementations of the System is depicted in Figure 1 below:-

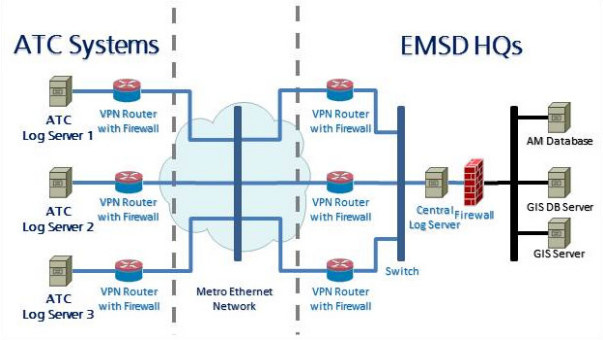

Fig. 1 System Overview

As illustrated in the System overview diagram, the AM database, the GIS server and the respective GIS database (DB) server are hosted within the EMSD network. Information from the AM database is transformed and loaded into the GIS-based Remote Monitoring System on a daily basis such that updates from the AM database can be reflected fully in the GIS-based Remote Monitoring System.

The remote ATC servers are connected to a Central Log Server located in EMSD through metro-Ethernet and VPN connections. A firewall has been deployed to separate the Central Log Server at the EMSD HQ for receiving log files from the remote ATC servers at agreed time intervals. Updated log files are typically synchronised to the Central Log Server every minute before the log files are converted.

The Remote Monitoring System was developed using ESRI ArcGIS version 10.2 and a relational database management system. The System is deployed on a

virtualised platform such that further expansion can be achieved easily when required. The Remote Monitoring System is connected to an EMSD internal network. Authorised users can access the System internally through the EMSD network or externally through departmental VPN connections.

3.3 User interface

Five operational layers have been implemented in the System to facilitate asset management activities:-

(a) *Traffic Light Fault History* – this layer provided a view of traffic light asset condition by traffic junctions based on the relevant asset fault histories. Traffic light icons in different colors are used to indicate the condition of the assets:-

Green – No fault in the last month
Orange – 1 to 2 faults in the last month
Red – 3 or more faults in the last month

Depending on the scale of map being viewed, the display of asset condition could be changed to show a summary of the number of junctions in different conditions grouped by districts as per Figure 2 below.

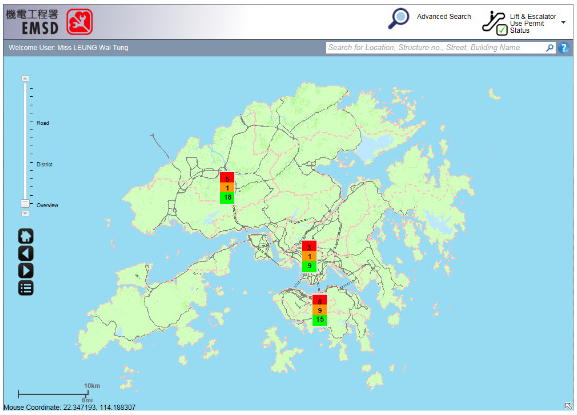

Fig. 2 Summary of Asset Conditions by Districts

When the map is being zoomed in to reveal more details, the display would be changed to present the status by individual junctions as shown in Figure 3 below.

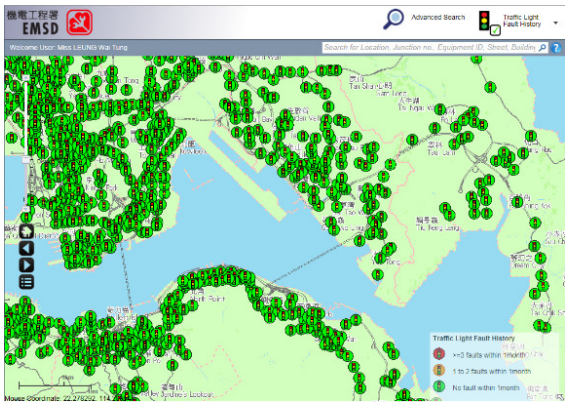

Fig. 3 Asset Conditions by Traffic Junctions

In addition, individual icon in the layer can be clicked to bring up an integral view on asset conditions, fault history summary, equipment details, geographical information, and equipment photos to about all levels of staff in EMSD.

(b) *Traffic Light Live Monitoring* – this layer shows the traffic light junction status based on updated ATC system log files that are delivered to the Central Log Server every 3 minutes. Traffic light icons with the following definitions are displayed:-

Green – Working
Orange – Minor fault at junction detected
Red – Major fault at junction detected

(c) *Lift & Escalator Fault History* – this layer shows the following conditions of lift/escalator by building structure (e.g. a footbridge or subway) using fault histories that are provided by maintenance contractor on a monthly basis:-

Green – No fault in the last month
Orange – 1 to 3 faults in the last month
Red – 4 or more faults in the last month

(d) *Lift & Escalator Use Permit Status* – this layer shows the below user permit status of lift/escalator by building structure (e.g. a footbridge or subway) using the relevant user permit expiry information.

Green – No fault in the last month
Orange – 1 to 3 faults in the last month
Red – 4 or more faults in the last month

(e) *Lift & Escalator Asset Condition* – this layer shows the conditions of lift/escalator by building structure (e.g. a footbridge or subway) using calculated scores from condition evaluation exercises performed for the managed lifts and escalators under the ISO 55001 asset management system of EMSD.

With these different layers available in the System, users can visualise the asset/equipment status and perform fault related analysis using a simplified approach.

Users can use the provided functions to look up asset information and related fault records summary with filtering options under a map view (see Figure 4). The System also allows users to examine the details (e.g. junction ID for traffic lights), related documents (e.g. photos and technical drawings), fault records, maintenance activities, etc., using the map display. The analysis result is useful for formulating a better life cycle management strategy for the associated assets.

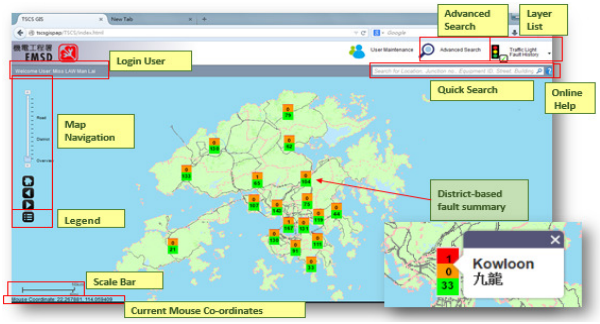

Fig. 4 User-friendly Graphical User Interface

The System under this project aims to provide user-friendly visualisation of the equipment status. The first phase of the project has provided functions for information look up as well as fault record summary of the traffic lights under the ATC systems with filtering options in map view. With a user-friendly graphical user interface (GUI), maintenance personnel and EMSD staff can search for details with a visualised location-based platform. Maintenance strategy can therefore be devised with ease.

3.4 Other Functions

The System has been developed with a vision for expansion. The System, for instance, is able to interface with external applications such as Google Map for cross-checking of the underlying geographical data.

The GIS System has been designed to be user-centric. Single sign-on has been included for convenient and secure access. In addition to the aforementioned functions, other functions are provided for identifying the assets. Examples include a quick search bar and an advance search module. The quick search bar allows users to search the position of the equipment on the map by junction number, equipment ID, street, or building name. The advance search filters assets with a similar but more detailed approach. Users can search by different properties including equipment type, controller model, district, structure number, location ID, contractor information and fault history. The System also allows authorised users to edit the location of the assets for on-going update of the asset.

3.5 Remote-monitoring

With the Phase II implementation of the System, live data from remote ATC systems is fed directly into the GIS-based Remote Monitoring System (see Figure 5) which alerts users of the current status of the monitored assets when necessary. Besides, this implementation does not require additional ATC workstations or the associated ATC APIs for operation, improving cost effectiveness.

Fig. 5 Status of Traffic Junctions Shown in the Live Monitoring Layer

Since the updated asset status has been captured in the Remote Monitoring System, further automation of the maintenance work could be considered, such as integration with the Enterprise Resource Planning System or the Messaging System of EMSD to allow even faster delivery of the information to the group of responsible personnel.

3.6 Market and Cost Performance

The System has enhanced the Asset Management System of EMSD, facilitating the maintenance of area-wide equipment, as well as contractor management, resulting in improved efficiency.

The integration of the System with the internal AM database of EMSD, has resulted in streamlined data collection process, as well as increased value of existing assets. This contributes to the corporate's endeavour in creating better value to the public.

3.7 Result and benefits

Since the launch of the System in late 2014, a significant drop in down time of equipment at traffic junctions was recorded (see Figure 6 below).

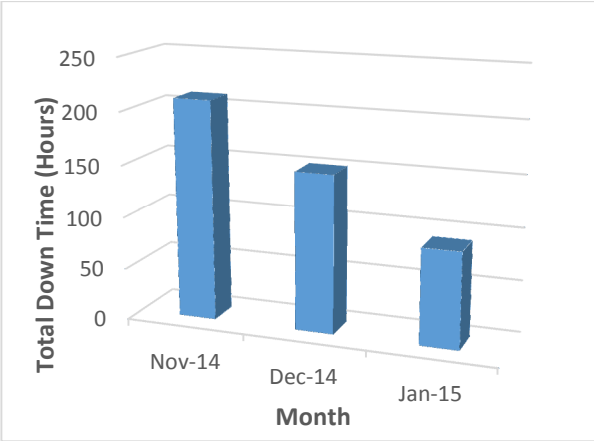

Fig. 6 Down Time of Traffic Light Junctions

4. WAY FORWARD

4.1 Further Developments

Following the launch of the GIS-based Remote Monitoring System, enhancement plans are devised to cover other electrical and mechanical assets under EMSD's maintenance; such as (i) electrical systems (viz. low voltage switch board, bus-bars, changeover switches, distribution & lighting systems) at around 300 locations, (ii) fire services and air conditioning installations at government premises and hospitals, (iii) flooding alarm systems, and (iv) renal equipment at the Hospital Authority. The System will later be integrated into the new EMSD corporate Building Information Modeling (BIM) System for better maintenance management.

4.2 Ultimate Goal

The ultimate goal of this project is to integrate the System and the bundled Asset Management (AM) System with EMSD's Corporate Building Information Modelling (BIM) System, which is expected to bring tangible benefits to asset data management, streamline workflow, and facilitate future upgrades, especially on fixed traffic control equipment and footbridge passenger conveyors, etc.

5. CONCLUSION

The GIS-Based Remote Monitoring System for Traffic Lights, Footbridge Lifts and Escalators benefits both the internal staff and the general public. Its unique design allows close monitoring of the equipment with minimal staff resources and downtime. Since prompt alerts are triggered following the occurrence of an incident, remedial actions can be taken timely. By upholding the standard of maintenance efficiency, the road safety and user experience is improved.

Acknowledgements

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References

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