Guest editorial

Facilities (special issue): smart city facilities and their management

The development of smart city is proliferating fast, and facilities are built or installed globally to coincide. Research pertaining to smart cities is growing; however, the topic is often focussed on technological innovation, with the facilities management aspect overlooked. In 2019, the CIB World Building Congress took place in Hong Kong. This congress is well known as the leading construction research and innovation conference worldwide promoting cooperation and information exchange between institutions in the building and construction sectors. During this Congress, fruitful discussions on smart utilities and facilities management were held, including the management of smart technologies for the built environment, smart service management, smart construction operations and smart property management.

We are delighted to see the various cutting-edge research studies presented in two particular themes of the Congress, namely, "Smart Utilities and Facilities Management" (CIB Subtheme) and "Facilities Management and Maintenance" (CIB Working Group: W070). Among the papers presented for these studies during the Congress, the authors of the high-quality ones were invited to extend their papers for submission to the current special issue: "Smart City Facilities and their Management". After a series of peer-review processes, eight papers were accepted for publication. An overview of each paper is shown below.

Effective hospital services form part of the initiatives for achieving "Smart Living". The first paper, using a phase-hierarchy (P-H) model, develops a list of systematically classified KPIs for managing hospital facilities. The model integrates two dimensions: the horizontal dimension covers the different phases (input, process and output) of facilities services delivery, and the vertical dimension refers to the hierarchical levels (operational, tactical and strategic) of a facilities management organisation. The authors first identified 61 indicators by reviewing the related literature. Then, a focus group meeting was conducted, with the KPIs classified according to the P-H model. Eventually, 18 KPIs were shortlisted, which fall into four aspects: "physical", "safety", "environmental" and "financial". These KPIs can be used for assessing the FM performance of hospitals, and further research may use the P-H model to classify performance indicators in other contexts.

The second paper, also related to hospitals, documents a smart building maintenance strategy by transferring the knowledge contained in BIM models to FM systems. In particular, the authors identified the bottleneck of using building maintenance systems alone. For example, although the information in building maintenance system could be updated using sensing data (e.g. monitoring data of heating, ventilation and air conditioning), the change of space (e.g. room size, function and the standard number of occupants) in the facilities could never be determined without the asset information updated in the BIM models. As such, the authors proposed to synchronise the information given in both building maintenance systems and asset information models to be updated via the use of BIM models. This was explored in six large hospital projects in China. Using the proposed method, the FM system can be smarter, featuring automatic and real-time information towards spatial-temporal changes and leading to efficient work at the facility operations and maintenance stage.

The third paper reports on the development of a data-driven artificial intelligence method to smartly analyse and predict the probability of water pipe failures. Regression analysis, genetic algorithm, machine learning, data mining and tree-based pipeline optimisation

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technique were used as the artificial intelligence techniques to automatically allow data cleaning and feature selection. Pipeline attributes, environmental factors and historical pipeline breakage records provided by industrial companies were considered as the input datasets. A real-life case study in Suzhou, China, was conducted to validate the proposed method. The method, as the study showed, has a great potential of providing effective prediction of pipeline failures with reasonable accuracy.

The fourth paper explores 4D BIM as an innovative solution to smartly manage the multi-utility data for relocation projects. A literature review, which summarises the 3D and 4D CAD models characteristics, was first conducted. Then, BIM for civil infrastructure and BIM for underground utility infrastructure were reviewed, followed by adopting a case-based methodology to collect data. The data sources were 2D maps, site observations, information, interviews, site visits and project documents. Driven by the data, 4D BIM models of existing and constructed utilities were developed using software tools, including Google Earth Pro and QGIS. Proved by the real-world projects in India, the application of 4D BIM models helps the project stakeholders to smartly manage utility relocations, with minimised delays and improved coordination.

The usage of smart technologies for measuring space utilisation in a facility is the focus of the fifth paper. With a literature review on the common methods and past studies about office space utilisation measurement, the authors pointed out that the space utilisation rates can be defined at minute-level or hour-level. The space utilisation rates at minute-level can be determined using sensor data, whereas those at hour-level can be determined using manual observation data. To determine the difference in the space utilisation rates measured by these two approaches, a case study was conducted on a commercial building in Italy. Five-month data associated with 35 rooms in the building was gathered and analysed. The results show that the space utilisation measured by sensors is on average 1.32 h less than the one based on manual observation. To enable limited space to be better utilised, it is encouraged to use smart sensors to determine space utilisation.

Data centres are among the essential infrastructures of smart cities. The sixth paper addresses the principal considerations of adopting data centre facilities in business organisations from a financial perspective. The authors identified the expected costs and benefits of data centre facilities based on the existing literature and a case study in Hong Kong. The study found that data centre services are owned by some organisations while used by some others on a co-location basis. Given the high land cost of metropolises and hence the significant development cost of data centres in such cities, the benefits of data centres should be carefully considered before making an investment decision. This study contributes to the understanding of the costs and benefits of developing and operating data centres for smart cities.

The seventh paper emphasises the importance of smart facility management for strengthening the connections between urban facility management and smart city development. The authors unfolded the problems of the existing governmental facility management policies for sustainable city development – mainly focussed on standardising the energy policy when managing existing facilities (top-down approach). In contrast, the development of smart cities is hindered by the complexity of collecting and analysing big data (tracking real-time facility performance) driven by smart facility applications (bottom-up approach). The authors used a case in Norway to reinforce that the top-down approach only helped to guarantee the national standards being imposed on social expenditures at the strategies level, whereas the *ad hoc* community vitality focussed on improving the living standard at individual level (bottom-up approach) may not apply to the whole city. As such, the authors shared their vision on the use of a bottom-up approach (digitalisations in managing facilities' workspace, maintenance and energy), facilitated by the top-down approach, for the development of smart organisations and smart cities.

The final paper introduces a game-based simulation system to smartly analyse crane lifting process in heavy industrial facility construction. The authors used Unity game engine to develop crane simulators based on the lifting capacity and kinematic movement of mobile cranes. Two case studies were given in connection with the single-player mode and multi-player mode. In the single-player mode, blind spots hindered the crane operator's ability to direct the lifting without the assistance given by the signal persons. In the multi-player mode, crane operator was able to overcome the blind spots when lifting the industrial facilities with the assistance given by the signal persons. This innovative system provides a systematic and effective approach to identify safety hazards and rehearse lifting processes by the use of real-time interactive computer simulations.

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