A BIM-DRIVEN METHOD FOR DEFINING WORK ACTIVITIES AND WORK ZONES OF CONCRETING WORKS IN HONG KONG BUILDING CONSTRUCTION

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ABSTRACT

In Hong Kong, Building Information Modelling (BIM), which stores the project data such as quantity and size of building components, has been recently encouraged as part of tender documentation for visualising the architectural design and construction process. In practice, however, BIM has not been widely used for measuring building works. Instead, quantity surveyors often measure the quantity of concreting works based on 2D engineering drawings whereas a project manager usually defines the concreting work zones and work activities based on his/her rough productivity estimates and the measured work quantity. The potential of using BIM models to allocate resources for placing concrete has yet to be explored. As such, this research study aims to develop a BIM-driven method for extracting and deriving relevant information and data from BIM model and relevant site records to smartly define the work activities and work zones of concreting trades for constructing a 40-storey reinforced concrete building superstructure in Hong Kong. Firstly, BIM information of building components is extracted from Revit BIM models. The data is categorised by floor levels and component types. The quantity data of building components is summarised in association with the work zones and component sizes using clustering analysis. Then, as-built site records are used to extract the activity duration and worker number for concreting works. Next, regression models are developed to characterise the analytical relationships between work quantities, work duration, and worker number. Based on the BIM information and regression models, better resource allocation strategies can be suggested for defining work activities and work zones of Hong Kong housing projects.

Keywords: Building information modelling, concreting works, construction schedules, clustering analysis, housing projects.

1. Introduction

Construction schedule is used as a project planning tool to guide the execution of sequenced activities in particular work zones and effectively utilise limited construction resources on site. The project planners estimate the number of site resources required to deliver a construction site activity within certain duration based on the available building information of, but not limited to, work content, worker productivity, work process, and construction methods. Notably, work content is defined as the amount of work required to deliver an activity measured in worker-hours. Nonetheless, in practice, the worker number and work duration required to deliver particular work content are estimated solely based on planner experience. It lacks systematic approach to define the work zones and work activities driven by BIM information (of building elements) and analytical relationships (between the worker number, work duration, and work content) for allocating limited site workers to deliver the projects on time.

Traditionally, the architects and engineers produced 2D CAD (Computer-aided design) drawings for communicating the engineering designs of building products using modern computers during project design stage (Czmoch and Pękala, 2014). Although the technologies and applications of 2D CAD are mature in construction sector, it remains difficult for users to store and retrieve the detailed building information (e.g., concrete volume based on slab dimension) of complex projects. As such, since 2000, BIM (Building Information Modelling), which is defined as "the development and use of a multi-faceted computer software data model to not only document a building design, but also to simulate the construction and operation of a new capital facility or a recapitalised and modernised facility" (USGSA, 2007), is being promoted in construction (Jung and Lee, 2015). BIM has the ability of storing, sharing, and archiving the building information using modern computers such that the communication between project stakeholders can be facilitated.

The adoption of BIM is increasing rapidly these years, especially in developed countries such as North America and Europe. In particular, the proficiency of BIM users (with "advanced" and "expert" level of BIM knowledge) in North America, Europe, Oceania, Middle East, Africa, and South America, reaches over 70% while the proficiency in Asia is only 46% (Jung and Lee, 2015). BSI Group, also known as the British Standards Institution, is the national standards body of the United Kingdom. BSI keeps publishing standards of BIM to promote its application. The latest BSI standard is "Specification for collaborative sharing and use of structured Health and Safety information using BIM". The aim of this standard is to use BIM information for managing and protecting the occupational health and safety of the workers and the public (BSI, 2018). Influenced by the global trend and its large potential of using BIM technology, the Hong Kong Government (HKG) and Construction Industry Council (CIC) have released guidelines to pilot and promote the BIM technology for construction applications. For instance, CIC established BIM standard to standardised the BIM application in 2015 (CIC, 2015), and HKG announced a technical circular for stipulating the BIM adoption requirement for tendering capital works projects in Hong Kong in 2017 (DevB, 2017). Although the current BIM adoption rate in Hong Kong is still progressing (Zhang et al., 2013), BIM technology shall eventually become accepted, and essential, for delivering all construction projects in Hong Kong.

In Hong Kong building construction, concreting work for superstructure construction always forms a critical path of a project schedule. In practice, the work content of concreting work is manually measured by quantity surveyors based on 2D CAD drawings. The measurement process is time-consuming with low accuracy. The project planners are overwhelmed by tons of information denoted in the 2D CAD drawings when determining the work content of pouring concrete for slabs and walls. As such, the number of concreting workers being allocated to deliver the activities in particular work zones for certain time is estimated by planners' experience. Although BIM models are commonly and simply used for detecting any clash of building components and visualising the construction process, the potential use of BIM information and worker deployment records to facilitate the definitions of work activities and work zones for concreting works in building projects has yet to be explored.

This paper proposed a BIM-driven method for smartly defining the work activities and work zones of a residential building in Hong Kong based on the concrete information and relevant data extracted and derived from the BIM model and site records. The rest of this paper is organized as follows: The literature review section describes relevant studies on standardising the BIM model and utilising BIM information for formulating and optimising construction schedules. Then, based on the BIM model and site records, the BIM-driven method is proposed for determining the work quantity of concreting work, and characterising the relationships between the work content, worker number, and work duration. Then, a practical case study of 40-storey reinforced concrete superstructure building construction is used to demonstrate its method application for defining the working zone and work activities to facilitate the schedule formulation and resource allocation. Finally, the effectiveness of the method is discussed.

2. Literature review

Building information modelling (BIM) is recognized as an emerging computer technology with the potential to improve the efficiency of construction information management in recent years. Research endeavours explored the potential use of BIM technologies in terms of (i) the use of information denoted in BIM models for establishing BIM standards, (ii) the use of BIM models for planning and control the construction process.

2.1. Construction BIM standard

BIM standards were established for evaluating the maturity of BIM models based on inherited BIM information. The level of details (LOD) of the BIM information given in the BIM model is used as a guideline to describe the sufficiency of the amount of information presented in a BIM model. In general, LOD is defined by the level of details of the information for presenting graphical components in a BIM model. The higher the LOD, the richer the BIM information. The LOD is used to classify a BIM model based on the information the BIM model has. The representation ranged from 2D drawings to 3D models attached with building information. Professional bodies, such as BIMForum (BIMForum, 2019), American Institute of Architects (Architects, 2019); AEC (Can) BIM Protocols (BIM, 2019), and BIMtaskgroup (BIMtaskgroup, 2019), attempted to standardise the LOD definitions. For example, AIA published “AIA E202-2008: Building Information Modelling protocol exhibit in 2008”. AIA and BIMForum jointly published “The level of development specification Part I and commentary” standard for building information and model in 2018 (AIA, BIMForum, 2019). This standard defines LOD 100 to LOD 500 to specify the minimum information requirements for describing any component in BIM model for each level. For example, in a LOD 300 BIM model, the model element is graphically represented in the model as a specific system, object or assembly in terms of quantity, size, shape, location, and orientation.

The definition of LOD and its application also attract the attention of researchers. For example, Leite et al. (2011) analysed the modelling effort when establishing BIM model at different LOD and the impact of LOD for the coordination of mechanical, electrical and plumbing (MEP) in a project. Fai and Rafeiro (2014) proposed a method including a single parametric model and workflow to establish an appropriate LOD for a BIM model of a project in Canada. In order to address incompetence in different LOD approaches, Ramaji et al. (2018) proposed a LOD-based cost estimation framework based on the exchange of information flow between BIM and cost estimation. Xu et al. (2019) proposed a seismic loss assessment method for building verified by the BIM data with respect to LOD. Cavalliere et al. (2019) quantified the environmental impact of building projects based on the BIM models developed with progressive LOD throughout project life cycle.

2.2. Construction process planning and control

Generate construction schedule efficiently can potentially save project cost and time. Research studies were reported on how to utilise the BIM information for construction planning. For example, Kim et al. (2013b) proposed a framework to automatically generate the construction schedules by extracting the BIM information, such as quantity, geometric, spatial, and material layer. Park and Cai (2015) proposed a framework for generating the construction schedule based on the BIM model by integrating both element and work breakdown structures. Some researchers attempted to use BIM models for operations simulation. Driven by BIM information, the level of details of operations simulation models can be improved (Wang et al., 2014). For instance, Lu and Olofsson (2014) proposed a BIM-DES (discrete event simulation) method by utilising the BIM information when conducting simulation runs. Liu et al. (2015) presented a BIM-based scheduling approach to formulate resource-constrained operations schedules by combining the use of work package information stored in BIM models, process simulations, and optimization algorithms. Nevertheless, BIM schedule can be optimised. For example, Chen et al. (2013) optimised BIM schedules by changing resource configurations in consideration of project objectives and project constraints.

Some researchers focused on tracking construction project progress based on BIM technologies. As BIM can be used as an information database (e.g., with time information), 4D (four-dimensional) BIM has the potential to be widely used for monitoring construction progress. For example, Kim et al. (2013a) tracked the project progress using both 4D BIM and sensor data which captured the work progress on site. Kang et al. (2016) designed a project management system by integrating nD CAD simulation with site photos to monitor construction progress. Wang et al. (2016) established construction progress curves using the time and cost information stored in BIM models. Han et al. (2017) proposed the geometry- and appearance-based reasoning methods for measuring project progress by contrasting as-planned BIM model and as-built construction process. Park et al. (2017) designed a central database structure by advancing web and database technologies to share real-time information of 4D BIM models. Hamledari et al. (2017) developed a field data capture technology is to automatically import the progress data to 4D BIM based on industry foundation classes. Park and Cai (2017) designed a WBS-based database structure for ensuring the integrity and order of construction documentation extracted from BIM models to assist project control. Recently, monitoring indoor construction progress is getting more attention. For example, Kropp et al. (2018) used computer vision algorithms by comparing the as-planned BIM data and as-built video data to determine the construction progress.

In overall, the BIM applications for construction management were widely explored. However, most studies proposed the methods for generating construction schedules and monitoring project progress based on BIM information. Based on the BIM information and site records, how to define the work activities and work zone are remained to be explored. As such, this research proposed a BIM-driven method based on BIM model and site records to characterise the work quantities of building elements and the relationships between the work content, worker number, and work duration of concreting work associated with a building construction in Hong Kong so as to facilitate the definitions of work activities and work zones in the projects.

3. Proposed BIM-driven method

This section proposed a BIM-driven method to facilitate the definitions of work zones and work activities. Figure 1 shows an overview of the proposed method. The method consists of four stages. Firstly, the relevant data is extracted from BIM models. The quantity take-off functionality in Revit is used to extract and classify the data. Then, data of particular attributes of a type of components is analysed in SPSS modeller to discover their importance and proportion. Clustering analysis is used to show the characteristics of work quantity associated with concreting work. Then, the site data of work quantity, worker number, and work duration are analysed based on site records (Form GF-527). Next, the relationships between work quantity, worker number, and work duration are characterised using regression analysis. Regression models are used to predict and define the worker number and work duration based on the work quantity. Lastly, the strategies of defining work activities and work zone for resource allocation are suggested.

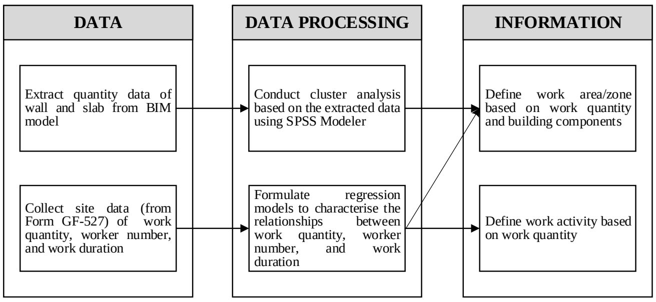

Figure 1: Overview of proposed method

3.1. Extract data of concrete quantity from BIM model.

The Revit BIM model for the project, which gives the information of building components including, but not limited to, location, volume, types and materials, should be firstly gathered. The model should meet LOD 300 requirement. The information of each building component is extracted in association with its height, type, length, width, location, material, height, area, family, function, unconnected height, and offset height. Figure 2 shows the quantity take-off function in Revit for extracting relevant information from BIM model. Then, the data is exported to Excel spreadsheet. The missing data, repetitive information, and useless information (e.g., the function, production stage, and repetitive types) would be cleaned and removed.

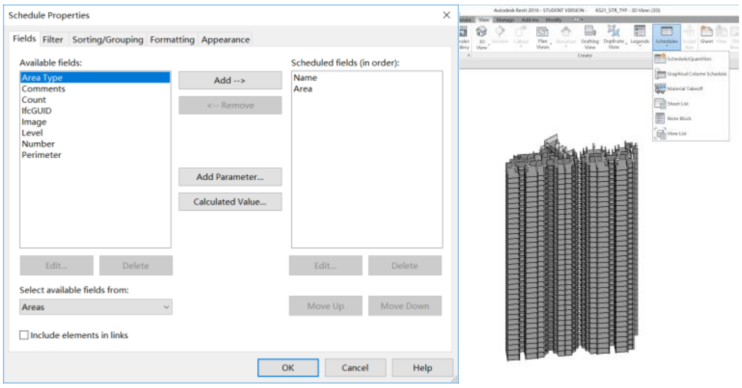

Figure 2: Quantity take-off function in Revit

3.2. Analyse extracted data using clustering analysis in SPSS Modeler.

The SPSS Modeler, which is a statistical software platform designated to analyse the data and develop predictions (Wendler, 2016), is used to cluster the extracted data. Data clustering is used to group the data items with similar features. *K*-means clustering is a commonly used technique to partition data set into *k* groups (MacQueen, 1967). Suppose a data set $X = \{x_1, x_2, ..., x_n\}, x_n \in R_d$ is given. *M*-clustering technique aims at dividing this data set into *M* disjoint clusters $C_1, C_2, ..., C_M$ such that *K*-means clustering criterion is optimised. The clustering rule is the sum of the squared Euclidean distances between the cluster center m_k of the subset C_k and each data point x_i (Likas et al., 2003). The clustering criterion of minimising the error is expressed in Equation (1). Notably, x is the value of each property (e.g., x = 9 if x denotes 9m^2 (area) of a concrete slab). Figure 3 shows a sample SPSS model for analysing the extracted data. The data of building element extracted from BIM model is imported into SPSS Modeler. The data are analysed using *K*-means clustering analysis. The data are clustered as per the element attributes of types, locations, perimeters, volume, height, and materials.

$$E(m_{1...}m_M) = \sum_{i=1}^{N} \sum_{k=1}^{M} I(x_i \in C_k) \|x_i - m_k\|^2 \quad (1)$$

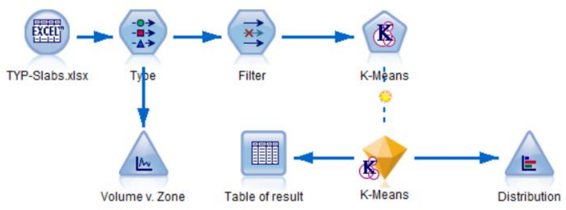

Figure 3: SPSS Model for K-means clustering analysis

3.3 Formulate regression models based on site records

This step characterises the analytical relationship between work quantity, worker number, and work duration. The information of worker number for delivering different concreting activities is assembled using site videos and worker deployment records (i.e., GF-527 forms). Equation (2) expressed the regression model describing the relationships between work quantity (dependent variable), work duration (independent variable), and worker number (independent variable). This equation materialises the general rules for defining the activities.

$$\text{Work quantity} = \beta_0 + \beta_1 \times \text{Work duration} + \beta_2 \times \text{Worker number} \quad (2)$$

3.4 Define work zones and work activities based on work quantity, worker number, and work duration

The definitions of work zone and work activity can be recommended based on the work quantity, worker number, and work duration. In practice, the working area in building construction will be divided into work zones. To maintain the continuity of resource utilisation, limited workers are allocated to work in particular work zone per date. For example, Worker 1 will perform the works in Zone A on Monday, Tuesday, and Wednesday. He will perform similar works in Zone B on Thursday, Friday, and Saturday. Therefore, working area should be divided in a way that the work content of the workers should be evenly distributed.

Besides, as mentioned, the site manager defined the worker number and work duration required for delivering concreting activities with particular work content solely based on personal experience. Given the BIM model and regression models, concreting activities can be defined reliably such that sufficient worker number can be allocated to deliver the work on time.

4. Practical case study

The practical application of the proposed method is illustrated using a 40-storey building project. The BIM model is shown in Figure 4. It is a residential building located in Hong Kong with the area of 3,517 m^2 and height of 122 m. Floors -3F to 40F and 4F to 39F are typical floors with same structure. This project adapts 6-day construction cycle to construct a typical floor of a superstructure in a week. The project planners divided a floor into two working zones (Zone A and Zone B). For concreting work, , the walls in Zone A and the slabs in Zone B are concreted on Day 3. The slabs in Zone A and the walls in Zone B are concreted on Day 6.The construction work of one floor is finished.

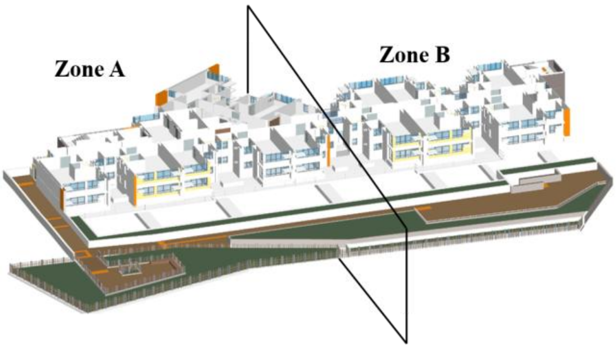

Figure 4: BIM model of a residential building

4.1. Extract BIM data

The 4F of the BIM model is chosen to extract the work quantity, in association with the concrete pouring work of wall and slab in Zone A and Zone B. The attributes of building component are extracted and exported in an Excel table (Table 1). Notably, some information of the building component is missing. For example, some components give the area and height information without volume and material information; the volume is not always equal to the product of area and height (this may due to the irregular shape of the components). Some information, including repetitive and useless information, are removed. For example, the information such as repetition of types, phase of creation, combined column, same height is deleted.

Table 1: Sample wall data being extracted

Family and types	Material	Height offset from elevation	Top elevation	Bottom elevation	Perimeter	Area	Volume	Zone
SLAB: HD_ARC_FLR_150mm	Concrete	0	27050	26900	17929.5	9	1.34	A
SLAB: HD_ARC_FLR_200mm	Wall-ARC	40	27090	26890	14299.8	6	1.12	A
SLAB: HD_ARC_FLR_150mm	Concrete	0	27050	26900	33833.2	13	1.9	A
SLAB: HD_ARC_FLR_200mm	Wall-ARC	0	27050	26850	13800	5	1	B
SLAB: HD_ARC_FLR_150mm	Concrete	0	27050	26900	130224.6	95	14.21	A
SLAB: HD_ARC_FLR_150mm	Concrete	0	27050	26900	11050	4	0.64	B
SLAB: HD_ARC_FLR_40mm	Wall-ARC	1415	28465	28425	7294.9	3	0.11	A
SLAB: HD_ARC_FLR_40mm	Wall-ARC	1415	28465	28425	7405.1	3	0.11	B
SLAB: Generic 160mm	Concrete	0	27050	26890	28400	27	4.35	A
SLAB: Finishes-200×200×7mm Wall Tile for Window Sill-23mm	Tile-200×200mm	963	28013	27990	1762.9	0	0	A
SLAB: Cement Sand-10mm	Cement Sand	2340	29390	29380	1740	0	0	A
SLAB: Generic 30mm	Concrete	75	27125	27095	560	0	0	A

4.2. Perform clustering analysis

After compiling the data, these data are imported into SPSS Modeler as the data source for clustering analysis. Figure 5 shows the scatter plot of wall volume in Zone A and Zone B. To determine the number of clusters, the errors of 3, 4, 5, 6 clusters are generated. The errors of 3, 4, 5, 6 clusters are 0.416, 0.412, 0.471, 0.471, respectively. Thus, four clusters were selected with minimum error.

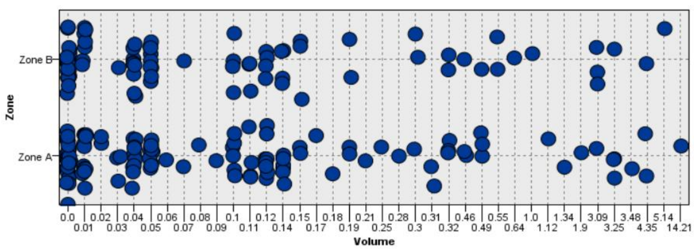

Figure 5: Scatter plot of wall concrete volume

The resulting distribution illustrates the volume categorised by the four clusters, two zones and component types. The result shows that Cluster 4 is the largest with a size of 82. Clusters 1 and 2 are relatively smaller with sizes of around 50. Cluster 3 is the smallest with size of 17. For the importance of each attribute, "height" has the highest importance and "location" has the least importance.

Figures 6-8 show the distribution of concrete volume as per the defined clusters, work zones, and slab types. Figure 6 shows that Cluster 1 and Cluster 4 have 19 types and 24 types of concreting volume respectively, and Clusters 2 and 3 only have 6 and 1 types of concreting volume. In Cluster 1, most of the concrete pour (more than 0.5 m^2) are large pours. In Cluster 2, the volume of slabs is around 0.1 m^2. In Cluster 3, the volume of slabs is 0.00m^2. In Cluster 4, the volumes of slabs are all below 0.5m^2. The "height" is the most important attribute for clustering. The "volume" shows a regular distribution in different clusters. The volume of slab may be related to its height. For instance, the volume of a large concrete pour (i.e., a large concrete slab) is unlikely to change subject to any small changes in height of the slab. However, the volume of a small concrete pour (i.e., a small concrete slab) is likely to change responses to any small changes in height of the slab.

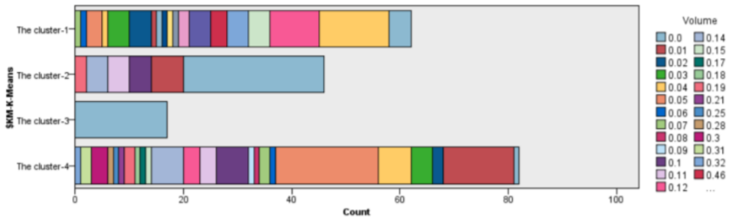

Figure 6: Distribution of concreting volume in four clusters

Figure 7 shows that the total amount of concrete in Zone B is around two-third of that in Zone A. The variety of the two zones is almost the same, which indicated that two zones have common features in structures. Considering the cost of resources (e.g., workers, machines, and materials), the concreting volume of two zones should be approximately equal so as to fully utilise limited site resources.

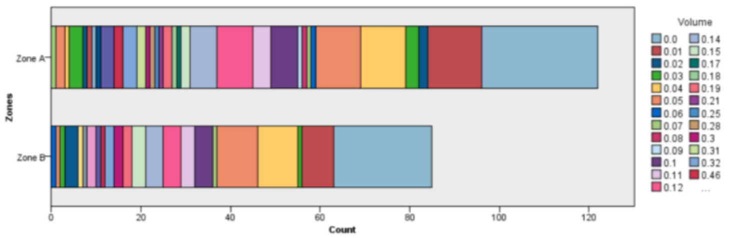

Figure 7: Distribution of concreting volume in two zones

Figure 8 illustrates the distributions of volume of different types of slabs. Notably, the volume for slabs with type "window sill" and "cement sand" cannot be defined as this information is missing in the BIM model. In general, the volumes of wall with the types of dark brown, light beige and tile are smaller than types "genetic" and "HD_ARC_FLR". It is because different types of slabs may be installed or constructed at different locations in a floor.

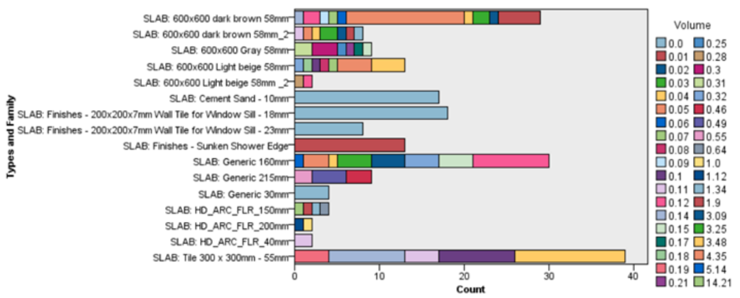

Figure 8: Distribution of volume for slab types

4.3. Formulate regression models

Table 2 summarises the work quantity, work duration and worker number for concreting work based on the site records.

Table 2: Work quantity, worker number and work duration of concreting work

Zone	Work types	Date	Worker number	Work duration (hour)	Work quantity (m^3)
A	Concreting slab	16/8/2018	10	1.467	38.000
		23/8/2018	10	1.550	38.000
		31/8/2018	10	1.550	38.000
		07/9/2018	10	1.767	38.000
		14/9/2018	10	1.600	38.000
B	Concreting slab	13/8/2018	11	2.500	60.000
		20/8/2018	11	2.533	60.000
		27/8/2018	11	2.667	60.000
		04/9/2018	11	2.700	60.000
		11/9/2018	11	2.623	60.000
A	Concreting wall	14/8/2018	9	3.983	80.000
		21/8/2018	9	4.000	80.000
		28/8/2018	9	4.067	80.000
		05/9/2018	9	4.650	80.000
		12/9/2018	9	4.683	80.000
B	Concreting wall	17/8/2018	10	6.267	112.000
		24/8/2018	10	6.200	112.000
		01/9/2018	10	6.800	112.000
		08/9/2018	10	6.733	112.000
		15/9/2018	10	6.600	112.000

To characterise the relationships between work quantity, worker number, and work duration, regression models are formulated in SPSS Modeler (Figure 9). Equations (3), (4), and (5) show the regression models of three concreting works of “concreting slab”, “concreting wall”, “concreting slab and wall (total)” respectively.

Figure 9: SPSS model for formulating regression models

Concreting slab:

$$\text{Work quantity (m}^3\text{)} = \text{Worker number} \times 22 + \text{Work duration (hour)} \times (-1.631e^{-13}) - 182 \tag{3}$$

Concreting wall:

$$\text{Work quantity (m}^3\text{)} = \text{Worker number} \times 3.453 + \text{Work duration (hour)} \times 11.72 \tag{4}$$

Concreting slab and wall (total):

$$\text{Work quantity (m}^3\text{)} = \text{Worker number} \times 2.197 + \text{Work duration (hour)} \times 14.59 - 4.33 \tag{5}$$

4.4. Define work activities

To illustrate the calculation for defining work activities, the wall in Zone B is taken as an example (Figure 10). The BIM model shows that the work quantity of concreting is 100.44 m^3. According to 6-day cycle, concreting workers should be worked for 6 hours. Based on Equation (5), the worker number of concreting could be estimated as 8 workers as per Equation (6).

$$\text{Worker number} = \frac{100.44\text{-}6\times14.59+4.33}{2.197} = 7.712 \tag{6}$$

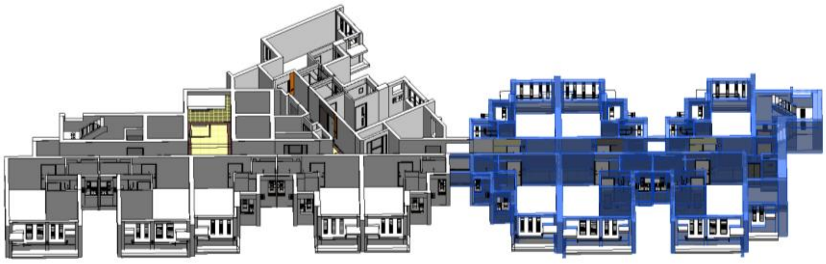

Figure 10: Extract the BIM data associated with wall elements

4.5. Define work zones

The site planners divided the working zone into Zone A and Zone B as shown in Figure 11. Notably, the slab and wall in one zone are not concreted simultaneously. Instead, the slabs in Zone A and wall in Zone B are constructed at the same time. After that, the walls in Zone A and the slabs in Zone B are constructed at the same time. In this paper, the difference of work content among two zones is considered as the only reason that influence the efficiency of the construction (no consideration of the steel reinforcement structure of two zones).

To minimise the difference of the work content associated with these two work zones, two schemes are postulated as Figures 12 and 13. For Scheme 1, the working zone of Room A re-allocated from Zone A to Zone B; for Scheme 2, Room B re-allocated from Zone A to Zone B. Table 4 shows the resulting work quantity. Based on 6-day cycle, work quantity is divided into two parts: AS (Slabs in Zone A) plus BW (Walls in Zone B); AW (Walls in Zone A) plus BS (Slabs in Zone B). In practice, the difference of work quantity is 16.14 m^3. For Scheme 1, the difference is 4.06m^3. Scheme 2, the difference is 5.42m^3. Thus, Scheme 1 is suggested as the optimal solution for defining work zones. Furthermore, the number of workers the concreting work of 6-day cycle could be calculated using Equations (3–5). For instance, the worker number in Day 3 and Day 6 is estimated as 36 and 34, respectively for Scheme 1.

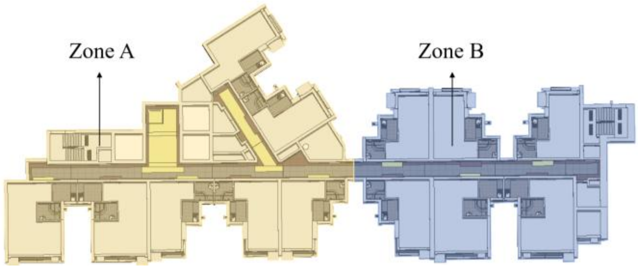

Figure 11: Definitions of Zone A and Zone B (Actual)

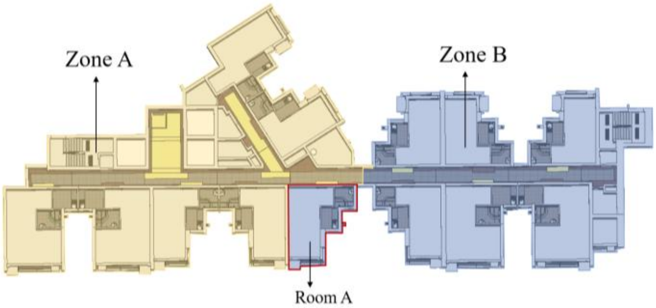

Figure 12: Definitions of Zone A and Zone B (Scheme 1)

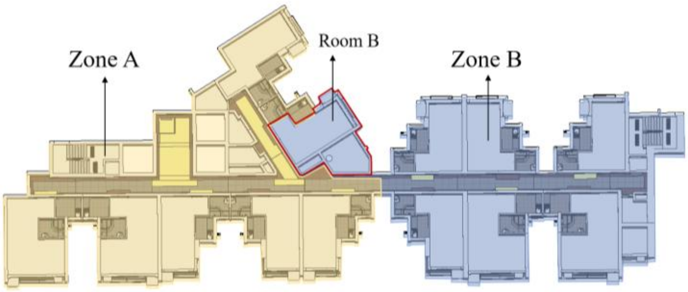

Figure 13: Definitions of Zone A and Zone B (Scheme 2)

Table 4: Volumes of slabs and walls in two work zones of different schemes

Components / Schemes	Slabs (m^3)		Walls (m^3)		Work quantity (m^3)		Difference
	Zone A	Zone B	Zone A	Zone B	AS+BW (i)	AW+BS (ii)	|(i)-(ii)|
Actual	48.98	35.46	130.11	100.44	149.42	165.57	16.14
Scheme 1	44.76	39.19	117.32	115.80	160.56	156.51	4.06
Scheme 2	44.31	39.73	115.79	116.62	160.93	155.52	5.42

Note: AS=Slab in Zone A; AW=Wall in Zone A; BS=Slab in Zone B; BW=Wall in Zone B

5. Conclusions

In this research study, a BIM-driven method for improving the concrete work schedule in Hong Kong housing construction is proposed. The method was verified using a practical case study of a 40-storey residential building in Hong Kong. Firstly, the quantity of building components is extracted from BIM models and stored in Excel; Secondly, these data are analysed in SPSS Modeler using cluster analysis to understand the clusters and distributions of building components; Thirdly, the data of work content, worker number, and work duration are collected from BIM model and site records, and the regression model is materialised to characterise the relationships between work quantity, worker number, and work duration. Lastly, based on BIM information and developed regression models, better resource allocation strategies by defining work activities and work zones are demonstrated.

In practical case study, the BIM data are divided into four clusters. The building components (e.g., volumes, distributions) can be analysed as per the clusters. This shows that the total amount of concreting work in Zone B is two-third of that in Zone A. Besides, the site records of work quantity, worker number, and work duration of concreting work in July are collected. Regression models are formulated to predict the number of worker based on work quantity and work duration (fixed in 6-day cycle). The work quantity of the walls in Zone B extracted from BIM model is chosen to predict the worker number using the formulated regression models. Finally, two schemes of dividing work zones are proposed and a scheme is selected as the best solution.

Unlike other BIM studies that focused on establishing system for formulating work schedules and monitoring working process, this research helps the definition of work zones and work activities based on BIM information and site records. The limitations of this research study are: the BIM model does not meet LOD 300 requirement such that information may not be accurate; the site records may not be accurate; the proposed BIM-driven method is designed for concreting work; the definition of work zone only considers the influence of the work content(without considering the steel reinforcement bars and construction joints). Future research may focus on developing a smarter method to extract BIM data from BIM model and worker data from site records for formulating the building schedules.

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