Development of a Cashflow Model for Monitoring Hospital Project Performance

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Abstract

Hospital projects, given their unique characteristics and features, are distinct from other types of construction projects. The development of hospital projects faces several challenges due to rapidly changing user requirements, multiple healthcare policy frameworks, and complexity of process. To keep success rates high, there is a need to support project management efforts and decisions with appropriate monitoring and control tools. This study develops a cashflow model for monitoring the performance of hospital projects in the construction industry of Hong Kong. The normalization and percentile techniques were integrated in analyzing the monthly cashflow data of public hospital projects completed in the past 20 years and constructing the model. The model provides alerts for three types of project performance, namely, green (or normal), yellow, and red performance. It helps in foreseeing existing or potential challenges in ongoing hospital projects and providing early warning signals for corrective actions to be taken effectively and in a timely manner. This study contributes to the Project Management Body of Knowledge by developing a model for enhancing hospital project delivery.

Keywords: Hospital projects; project management; project performance; monitoring and control; performance modelling; cashflow model; construction industry; Hong Kong.

1 Introduction

The pace of population aging has been ramping up in the past years in Hong Kong. According to the "Hong Kong Population Projections 2020-2069" released by the Census and Statistics Department of the Hong Kong SAR government (C&SD), the population aged 65 and over accounted for 18% of the overall population in 2019. Furthermore, the aging trend in Hong Kong will continue to accelerate in the future. It is estimated that there will be 2.58 million older people in 50 years, accounting for 38.4% of the total population in Hong Kong (C&SD, 2020). The aging trend will be accompanied by increasing healthcare needs. Currently, it requires a concerted effort across industries and the government to provide adequate healthcare services to all residents in Hong Kong. To cope with the challenges of the aging population and satisfy growing healthcare needs, the Hong Kong SAR government has formulated two 10-year hospital development plans costing about US$64 billion to upgrade, expand and develop healthcare facilities (International Trade Administration, 2022). In 2016, the Hong Kong SAR government set aside a dedicated provision of HK$200 billion for the implementation of the first 10-year hospital development plan (HDP) in the coming ten years; the 10-year HDP comprises construction of one new acute hospital, redevelopment and expansion of existing 11 hospitals, construction of three new community health centres and construction of one new supporting service centre (Hospital Authority, 2016). Subsequently, the government planned the second ten-year HDP in 2018, and several hospital projects have been included in the second ten-year HDP to boost its inpatient capacity, enhance service quality, and renew its building facilities (Legislative Council Panel on Health Services, 2019). Compared with general projects, hospital construction projects require more complex functions and stronger professionalism. Moreover, hospital projects also face various challenges, such as long construction periods, enormous investments and multiple stakeholders. The complexity, uniqueness and challenges may endanger the ultimate success of hospital projects. Cost and time are critical parameters of hospital projects and driving forces of success. However, in addition to time overrun, cost overrun is a common phenomenon and associated with nearly all projects in the construction industry (Azhar et al., 2008). Apart from construction factors, the major reasons for delays and cost overrun in the public projects of Hong Kong include funding approval delays, the need to re-design, inclement weather conditions, and deployment of additional resources to deal with other unforeseen circumstances etc. Effective cost and time control can decrease the hazards of failing to deliver hospital projects. Monitoring the cashflow is crucial in cost control for the project success. Nevertheless, specific methods of monitoring cashflow of hospital projects are relatively limited. Hence, it is necessary to develop an effective tool for monitoring the cashflow of hospital projects, which enables stakeholders to predict potential problems in the implementation period and provide early warning signals for early intervention. This study aims to develop a cashflow model for monitoring the performance of hospital construction projects to provide an effective tool for stakeholders to deliver hospital projects successfully.

2 Literature Review

2.1 Development of Healthcare Projects in Hong Kong

In the initial period, healthcare services of Hong Kong were mainly provided by charities. In 1872, Tung Wah Hospital, the first private charity hospital in Hong Kong, was founded with the support of Chinese pioneers. People's growing medical demands constantly stimulate the dynamic development of healthcare projects. In 1894, an unprecedented plague pandemic in Hong Kong killed more than 2,000 people of Hong Kong and forced a third of the population there to flee. In 2003, SARS swept through Hong Kong. Furthermore, Hong Kong has been encountering the challenges of various epidemics, such as the Middle East Respiratory Syndrome (MERS), influenza pandemic, Ebola virus disease, Zika virus infection, Dengue Fever, COVID-19, and Monkeypox. There is a large elderly population in Hong Kong, with 1.27 million people over the age of 65 vulnerable to severe COVID-19. Simultaneously, considerable number of residents face the threats of various diseases in Hong Kong, especially the elderly group. Healthcare services in Hong Kong have been under extreme pressure with the spread of a series of infectious diseases and other chronic diseases of the elderly. Subsequently, a variety of healthcare services of Hong Kong have been developed for satisfying the healthcare needs of the public, such as primary medical care services, hospital services, tertiary and specialized services, elderly, long-term and rehabilitation care services, integration between public and private sectors, and infrastructure construction (HKGovernment, 2005). However, over the past decade, increasing hospital floor space per bed was offset by declining hospital beds per population. According to statistics from the Hospital Authority, the number of hospital beds per capita in Hong Kong has generally dropped from 4.94 to 4.07 per 1,000 people. To solve this asymmetrical problem, the construction, reconstruction and expansion projects of hospitals are in process to enhance healthcare services.

2.2 Characteristics of Healthcare Projects

Healthcare projects are complicated, in accordance with rigorous security measures, strict sanitary conditions, procurement of special medical equipment, and complex requirements for managing large databases (Sebastian, 2011). As a healthcare facility, it needs to meet the accommodation and clinic requirements, guarantee operational efficiency, conform to aesthetics standards, and facilitate practical use. Javed et al. (2013) illustrated that the hospital project requires a comprehensive functional demand, including sustainability, accessibility and safety. The hospital project is supposed to follow the principles of "green building system", which means it ought to create green indoor and outdoor environment, save energy consumption, use environmentally friendly materials and equipment, utilize new construction technologies, and reduce the pollution of air, water and waste. Patient-oriented design is also the focus of hospital projects. This design is embodied in various particulars, such as the functional design of buildings, decoration, supplementary healthcare facilities, medical equipment and so on. Moreover, hospital projects have attached much importance to intelligent and automated systems, which are different from general construction projects. The current hospital requires diverse information management, integrating common management systems, high-standard medical data systems, as well as specific image processing systems for radiology, ultrasound and speculum. The requirement for automatic management of medical equipment and dynamic security management system is also a significant feature of hospital projects. The cashflow patterns of healthcare projects are quite unique because of the high furniture and equipment (F&E) cost allocation to largely meet the abovementioned requirements. These unique cashflow patterns have implications for the performance of healthcare projects as compared to general construction projects. Essentially, the complexity and uniqueness of healthcare projects create challenges for the successful delivery of those projects.

2.3 Definition of Project Success

Stakeholders tend to pay great attention to the project success. The success of a project is achieving pre-planned goals, and it's also the ultimate goal pursued by stakeholders. The project success is always regarded as a combination of specific and subjective goals listed in the success criteria. The success of a construction project, which is generally considered as being accomplished on time, within budget and meeting quality requirements, is featured to achieve many preferred outcomes over the usual demands (Adaurhere et al., 2021). Wahaj et al. (2017) deemed that the project success ought to meet clients' requirements and obtain their satisfaction. Additionally, sustainability and conforming to the specifications are also parts of the criteria of project success. However, the criteria of project success are controversial and difficult to pin down. Although various approaches to determining project success have existed, they are almost on the basis of the iron triangle of time, cost and quality. Nonetheless, the success of any construction project cannot be limited to the scope of the iron triangle. Currently, the multi-dimensional framework plays a critical role in assessing the project success, integrating the traditional iron triangle, effective resource management, quality and stakeholder satisfaction (Kimaru, 2019). Nevertheless, the terminology project success is fundamental to managing and controlling current projects so as to plan and guide future projects.

Time criterion is essential in construction projects in Hong Kong because the jurisdiction of Hong Kong has gained a good reputation for excellent speed when carrying out construction projects. Studies have shown that construction projects in Hong Kong have undergone high-cost upgrades. Cost and time criteria have been studied as interrelated concepts in projects, which meet the conventional definition of project success as within the budget and deadlines specified in the contract (Larsen et al., 2016). Planning for time and cost prior to design and construction stages contributes to improving user satisfaction, reducing project duration and cost, hence advancing the success of project.

2.4 Role of Project Monitoring

Project monitoring involves tracking the project's performance indicator, progress, and associated tasks to ensure that a project is completed on time, within budget, and meeting quality requirements and proposed standards to achieve its successful delivery. Project monitoring can contribute to identifying obstacles or problems that may arise during project execution so as to allow stakeholders to take action to cope with these issues in time. Project success usually relies on effective and dynamic project monitoring. Effective project monitoring enables project managers to gather valuable data of project progress and utilize the collected data to make informed decisions. Collaborative forecasting of cost and time is a crucial tool for effectively monitoring, controlling and managing projects from inception to completion. Large variances in cost and time can significantly affect the cash flow, profitability and viability of a project. Hence, it is necessary for project managers to forecast these variances and make the prediction accurate in early stage to deal with various issues involving stakeholders and financial planning, which facilitates the successful project implementation (Li et al., 2006). Especially in the construction industry, project managers believe that predicting the cost of completion is the most important function of project control technology (Kim et al., 2003). It is vital for project managers to skilfully predict the amount of deviation from the original budget of a project.

2.5 Relevance of Cashflow Forecasting

Project cashflow has attracted the widespread concern from both contractors and clients. Adequate cashflow is necessary to achieve three fundamental goals in project management. Firstly, the sufficient cashflow contributes to covering the costs in terms of management, material and labour for the project. Secondly, the ample cashflow is needed to decrease the financial liabilities that the company may have to assume during the project implementation. Additionally, adequate cashflow is key to executing construction activities on schedule, as cost and time are interdependent parameters (Al-Joburi et al., 2012). In summary, the effective management of cashflow is pivotal to the profitability and survival of any construction enterprises. As the project progresses through various phases, contractors are supposed to try to avoid taking on work under additional loads without regard to schedule requirements. Hence, it is important for contractors to ensure sufficient cashflow before meeting schedule requirements (Al-Joburi et al., 2012). The ineffective construction financial planning can lead to significant escalations of cost and schedule, which may extend to the financial collapse of the entire construction project. From the perspective of clients, cashflow forecasting is the basis for their commitment to pay contractors on time at the appropriate stage of the project. To ensure timely payment and keep contractors working, clients need to forecast cashflow accurately to drive the project implementation. Ultimately, appropriate monitoring and control of cashflow will contribute to the successful delivery of projects, hence the satisfaction of clients and other stakeholders.

A variety of methodologies have been used for forecasting cashflow to monitor the project performance. Some forecasting methods exhibit high-degree inaccuracy in terms of strategic misstatements and optimistic biases, such as baseline estimation, Monte Carlo simulation, and earned value management. For instance, the average inaccuracies of cost forecasts for transport infrastructure projects are 20.4% for roads, 33.8% for bridges and tunnels, and 44.7% for railways (Flyvbjerg, 2008). More advanced methods are being developed to overcome these prediction problems in projects.

3 Research Methods

As can be emphasized, different types of projects exhibit distinguishing characteristics and features as well as performance norms. Hospital projects are of special characteristics and differentiated from other types of construction projects by their complexity regarding the (1) dynamic interactions of systems, subsystems and elements; (2) massive quantity of information and requirements; (3) high degree of changes and change management; (4) evolving conflicts and interactions between healthcare legislations and policies and hospital project requirements; and (5) diverse, multiple and complex healthcare policy frameworks issued in fragments over time (Soliman-Junior et al., 2021). Hospital projects may similarly possess these features and characteristics particularly when developed in the same geographical jurisdiction. Therefore, it is logical and reasonable to develop a singular cashflow model for the purpose of evaluating, monitoring and controlling hospital project performance in Hong Kong. The cashflow model is meant to emphasize the famous relationship between cost and time on the performance of hospital projects. The study employs a purely quantitative approach to analyze the cashflow dataset of completed hospital projects.

3.1 Data Collection and Preparation

The focus of the study is on the public sector and so cashflow dataset of hospital projects completed in the past 20 years under the Capital Works Programme was obtained from the Development Bureau of the Hong Kong SAR. A number of measures were put in place in order to make the cashflow dataset appropriate and reliable for analysis. This further ensured that the real cost-time settings of the hospital projects were properly incorporated into the cashflow dataset for analysis. The measures employed include: (1) eliminating hospital projects with incomplete and/or irrelevant cashflows from the dataset to avoid contamination, (2) retaining only hospital projects with durations of more than two years in the dataset, (3) compiling all hospital project cashflows in the dataset on monthly basis for easy analysis, (4) using the substantial completion dates as the common criterion for determining the completion durations of all hospital projects. Substantial completion is "*the time or date when the entire construction, or a designated portion thereof, is sufficiently complete such that the construction can be occupied and used by the owner for its intended purpose*" (Nabi et al., 2021). Out of a population of 43 public hospitals and institutions in Hong Kong (Hospital Authority, 2023), the cashflow dataset of 19 hospital projects meeting the abovementioned criteria was obtained for analysis. Other project information obtained includes project name, budgeted costs, actual costs, planned durations, final durations, start and finish dates, etc.

3.2 Data Analysis Process

To fully analyze the hospital project cashflow dataset and develop the cashflow model, the process followed is explained in the following subsections.

3.2.1 Normalization of Cashflows

Normalization is the process of developing standard durations or data points to allow for several hospital projects of different durations to be acceptably compared on the same basis. Thus, instead of developing a number of month- or year-based cashflow models for different durations in normal circumstances, a singular stage-based cashflow model developed with the help of normalization is adequate to perform the same monitoring function. The usefulness of normalization in this study includes the: (1) prevention of potential false alarms at the early stages of hospital projects due to the cumulation of cashflows in the model, (2) ease of conducting like-with-like comparisons of several hospital projects with just a singular model, and (3) potential of organizing several cashflows of hospital projects into a singular powerful database in a more consistent and flexible manner. Normalization is noted to be a potent method for resolving and organizing similar distributed project information in past studies (e.g., Development Bureau (2018a)).

Since the durations of the 19 hospital projects are different, it is important to normalize the durations into equal standard stages by using the substantial completion dates as the common factor. This enables the cashflow performance of hospital projects with different durations to be easily and logically compared. Essentially, the normalization method divides the substantial duration (i.e., from the start date to the substantial completion date) into ten successive equal stages and then sums up the respective monthly cashflows within each stage. Equation 1 is the formula engaged for calculating the cumulated cashflows for the X^{th} one-tenth stage of the substantial durations.

$$Q_{SX} = \sum_{Y=1}^{t} Q_Y + \left[\left(\frac{n}{10} \times X\right) - t\right] \times Q_{t+1} - \sum_{Z=0}^{X-1} Q_{SZ}$$

Equation 1

where, $\left(\frac{n}{10} \times X\right) - 1 < t \leq (\frac{n}{10} \times X)$ and t is a positive integer, n is the project duration in months, Q_t is the amount of cashflow in the t^{th} month, Q_Y is the amount of cashflow in a particular month, Q_{SX} is the total amount of cashflow at a particular stage, Q_{SZ} is the total amount of cashflow at any prior stage, and $Q_{S0} = 0$.

After obtaining the stage-wise cashflows, it is necessary to cumulate them forward-wise from stage one to stage ten. Therefore, Equation 2 is utilized for computing the cumulated cashflows from the project start date up to the X^{th} one-tenth stage of the substantial durations.

$$Q_{TX} = \sum_{X=1}^{10} Q_{SX}$$

Equation 2

where Q_{TX} is the sum of all cashflows up to X^{th} stage, and Q_{SX} is the cashflow at a particular stage of project.

At the next stage, the relative proportion of each cumulated cashflow at the X^{th} one-tenth stage of the substantial duration to the final project cost (i.e., Q_{PX}) is obtained using Equation 3.

$$Q_{PX} = \frac{Q_{TX}}{Q_T} \times 100\%$$

Equation 3

where Q_{TX} is the sum of all cashflows up to the X^{th} stage and Q_T is the final cost of the project.

3.2.2 Development of Cashflow Model

The graphical cashflow model is developed to express the true standard relationship between the normalized durations and cumulated cashflows of hospital projects. In effect, it will serve as a standard tool to check the cashflow performance of hospital projects. The cumulated cashflow percentages at the ten normalized stages for all hospital projects are compiled, and specified percentiles of the cumulated cashflow percentages are extracted for developing the model. The model comprises four different cashflow patterns that demarcate the boundaries of three performance and risk zones. Cumulated cashflows of new hospital projects falling within these zones will provide quick performance and risk alerts for project managers and decision-makers to investigate existing or potential underlying problems and take corrective managerial actions where necessary. The objective is to ensure that about 70% and about 95% of the cumulated normalized cashflows are found between the two inner patterns and the two outer patterns respectively (Development Bureau, 2018b). The explanation supporting this approach is that project cashflows that are closer to the median cashflow pattern are of better performance, and vice versa. Accordingly, the 2.5th, 15th, 85th and 97.5th percentiles are calculated for the cumulated normalized cashflows at the individual stages by using Equation 4.

$$P_i = \left(\frac{i[n+1]}{100}\right)^{th} \text{ item in the ascending list of values}$$

Equation 4

where P_i is the ith percentile of the list of cumulative normalized cashflows at a particular stage and n is the sample of projects in the category under consideration.

4 Results and Discussion

The dataset reveals significant ranges of the final costs (i.e., about HK$200M to HK$8,800M) and actual durations (i.e., about 18 months to 108 months) of completed hospital projects. It is observed that the hospital projects perfectly experienced cost underruns of as much as -33% and an average of -17%. Some hospital projects however experienced time overruns. Generally, hospital projects in Hong Kong are executed within the original budgeted costs whereas some overrun their planned durations. The sample properly captures different scopes, scales and complexities of hospital projects to cover the known unique characteristics and features.

The normalized cashflow model of the hospital projects is illustrated in Figure 1. The normalized cashflow model terminates project expenditure at the substantial completion dates, and hence, the curves are not expected to reach 100% of expenditure. The rest of the project expenditure is made in bits and less consistently over a very long period after the substantial completion date because the major works are already completed. The percentile curves linking the cumulated normalized cashflows in the model provide an avenue to divide cashflow performance of hospital projects into zones. By interpretation, each performance zone manifests a matching potential risk of overrun that should be investigated to inform on specific corrective actions in projects. Whereas the green zone indicates the least risk of overrun, the yellow zones show the medium risk of overrun, and the red zones point to the highest risk of overrun in terms of cost and time performance. Particularly, the cumulated cashflow of a new hospital project falling into the upper yellow and red zones means the potential of cost overrun than time overrun occurring, whereas falling into the bottom yellow and red zones indicates the likelihood of time overrun than cost overrun happening. It is only when the cashflows of new hospital projects fall within the green zone that project managers and decision-makers can assume that all is well regarding cost and time performance. Otherwise, an investigation should be carried out on project experiences to disclose any foreseeable underlying problems and subsequently apply corrective measures in projects.

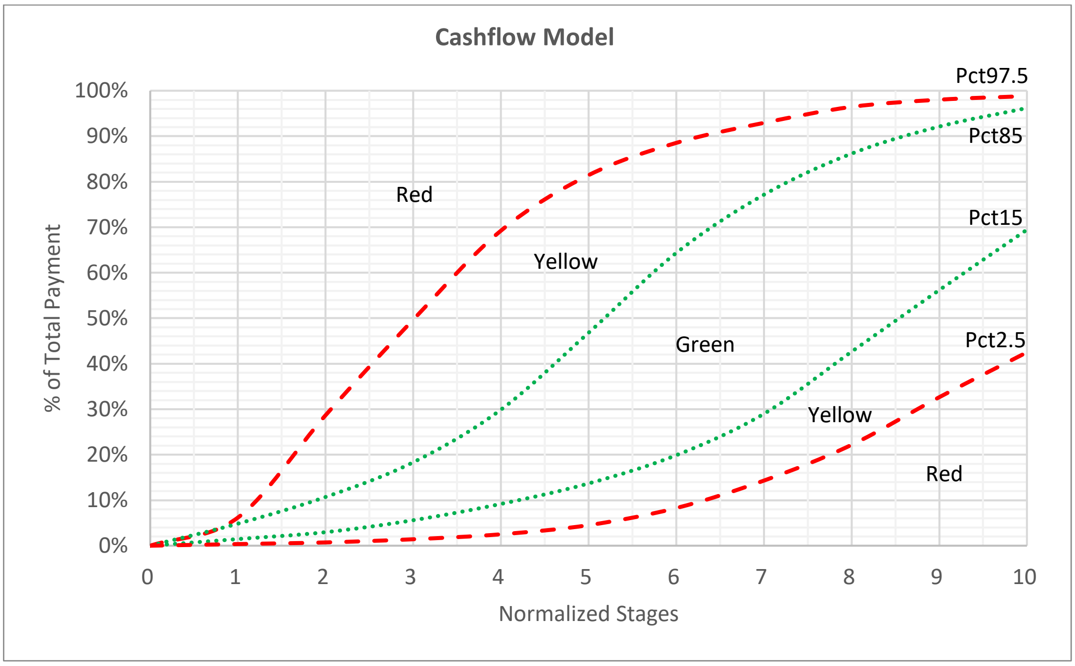

Figure 1: Cashflow model for hospital projects

Although specific cashflow models of hospital projects are lacking in literature of contemporary times, cashflow models of other types of projects or general projects have been proposed. For example, Mills and Tasaico (2005) developed two polynomial regression models using time and project attributes to estimate monthly cashflow for 336 transportation design-build projects completed in North Carolina. The developed regression model does not show reasonable accuracy beyond a 12-month forecasting horizon (Liang et al., 2021). Ock and Park

(2016) developed an algorithm for forecasting cashflow of a construction project in the planning stage according to daily cashflow. This algorithm considers factors such as time lags, cost categories and the cost category weight on earned value and budget. Nevertheless, the applicability of this cashflow forecasting algorithm hinges on further validation. Cheng et al. (2020) put forward a model using the deep learning technique for forecasting cashflow of construction projects. This model relies on independent variables and time-dependent variables, and the independent input variables representing project complexity include the number of floors, contract costs, floor area, and project duration. It may be considered as a great model for forecasting future cashflow of construction project to some extent, while it turns out to be complicated due to the complexity of using deep learning technique in practice. Moreover, it requires a large amount of data of real cases for training the model, which increases the difficulty of applying this model. Msawil et al. (2021) developed a heuristic cash flow forecasting model for infrastructure projects. This model offers detailed assessment of the potential behavior of the cash flow trends at both the resource and work package levels, which can be served as a tool for practitioners to forecast the cashflow of infrastructure projects. Despite the contribution, it cannot be fully generalized to other types of projects. Weytjens et al. (2021) compared different cashflow forecasting models and disclosed that some classic cashflow forecasting techniques such as ARIMA and Prophet were limited in terms of flexibility and accuracy of prediction.

In contrast, the cashflow model developed in the current study is a specific model that will provide better monitoring and forecasting functions in hospital projects than the aforementioned models. It provides a good basis for all hospital projects to be equally monitored and forecasted by the normalization of monthly and yearly durations into stage-based durations. Thus, it can reliably monitor and forecast several ongoing hospital projects with different durations at the same time for comparison and benchmarking purposes, which considerably enhances its usefulness and flexibility in practice. Following the normalized duration approach, the accuracy of the cashflow model in monitoring and forecasting should be about equal for short-term, medium-term and long-term hospital projects sharing similar features and characteristics. Another important attribute of the cashflow model that fills research gap is that it somewhat analyzes the level of risk regarding time and cost problems in hospital projects by the indication of green, yellow and red alerts. From a practical perspective, the cashflow model is more effective in terms of detecting existing or potential problems in hospital projects and providing early warning signals to project managers and decision-makers. The study innovatively adopted the method integrating normalization and percentiles to develop the cashflow model. This integrated method is unique because of the simplicity of normalizing cashflows, extracting the percentile-based cashflow patterns, and constructing the cashflow curves to model different performance zones. As more hospital projects are completed and the underlying database expands, then the accuracy of the reconstructed cashflow model in monitoring and forecasting ongoing hospital projects will significantly improve. Besides, basic know-how of mathematics and graphing tools (e.g., Microsoft Excel) will enable researchers and practitioners to adopt the method in developing applicable cashflow graphs for monitoring different project types with common attributes e.g., railway, tunnel, road and school projects.

5 Applications of the Cashflow Model

The cashflow model is useful for several reasons including comparison, benchmarking, evaluation, monitoring, controlling, forecasting and enhancement of hospital project performance.

5.1 Comparison and Benchmarking of Performance

A major function of the developed cashflow model is to provide a good basis to compare several hospital projects with different durations. When the durations and cashflows are maintained in the original monthly formats, comparing projects with different completion durations will be difficult and questionable. This is because several cashflow models would be needed to monitor the performance of multiple hospital projects with a wide range of completion durations. However, the normalization process solves this problem by ensuring that all projects could be equally stretched over ten duration stages up to their substantial completion dates for easier comparison. The developed cashflow model is more inclusive, flexible and effective, and it emphasizes like-with-like comparisons of an unlimited number of hospital projects in Hong Kong.

5.2 Evaluation and Monitoring of Performance

By evaluating a new hospital project with the model, the present status, immediate future status, and completion status of performance could be known with a significant level of confidence. The cashflow performance correlates not only with the durations exhausted but also with the work packages completed in hospital projects. Adverse evaluation results mean hospital projects are likely to experience cost and/or time overruns, whereas positive evaluation results imply that hospital projects would conceivably remain within cost and time targets. Three hypothetical projects, A, B, and C are presented in Figure 2 to illustrate how the developed cashflow model can evaluate, monitor, and control hospital project performance. Project B has maintained cashflow performance in the green zone after stage one, Project A has largely alerted cashflow performance in the yellow zone, and Project C has its cashflow performance changed from the yellow zone to the red zone. By implication, Projects A and C show moderate and high risks of cost and/or time overruns occurring. Specifically, Project C manifests that there is probably (1) underpayment for work packages completed so far, (2) back-end loading such that major work packages are scheduled to be completed in the tenth stage, (3) series of minor work packages to be carried out after the substantial completion date, or (4) insufficient substantial duration to accomplish all main work packages. With this background knowledge, project managers and decision-makers are guided in implementing necessary measures to monitor and control the progress of these hospital projects in order to realize set targets. The underlying causes of the problems experienced in hospital projects are not directly revealed by the evaluation results. The results only point to the fact that the hospital projects are experiencing problems that need to be investigated. The investigation will reveal underlying causes such as technology failure, ineffective coordination of activities, unforeseen ground conditions, payment problems, poor resource quality, change in design, material shortage, variation orders, land acquisition and readiness, ineffective cost and schedule control, complexity and complication, inflation and exchange rates, worker turnover, execution mistakes, and contractual problems.

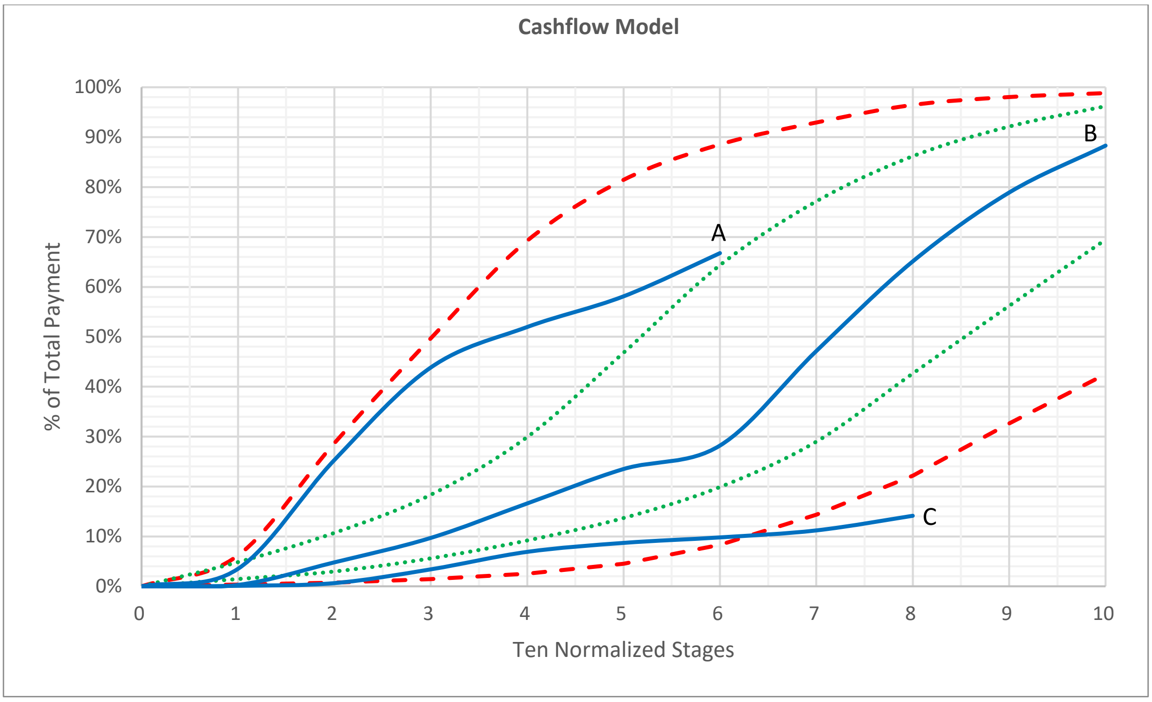

Figure 2: Demonstration of evaluation and monitoring of performance

5.3 Enhancement and Forecasting of Performance

Additionally, the cashflow model is helpful in enhancing and forecasting the cashflow performance of hospital projects. Upon identifying the specific problems troubling hospital projects, project managers and decision-makers must take corrective measures to restore cashflow performance to the green zone as much as practicable. The corrective measures are expected to help enhance the performance of hospital projects in terms of cost and time. For instance, when unexpected ground conditions cause the cost of excavation, ground preparation and other works at the early stages to exceedingly increase, there would be overpayment for these works as compared to the initially available budgets. By revising and increasing the available budget to a commensurate level, the cashflow performance of the project will return to the green zone. Figure 3 presents a revision to the cashflow performance of three hypothetical projects A, B and C upon the application of corrective measures where necessary. Project A initially experienced overpayment for the work packages completed so the project budget is increased by about 60% and this returns its cashflow performance to the green zone. Project B requires no corrective measures, and it is left in the original experience of cashflow performance in the green zone. Project C is granted a 100% extension of time, and this upgrades the cashflow performance to the green zone. Note that the corrective measures are implemented only for the sake of demonstration and clarification.

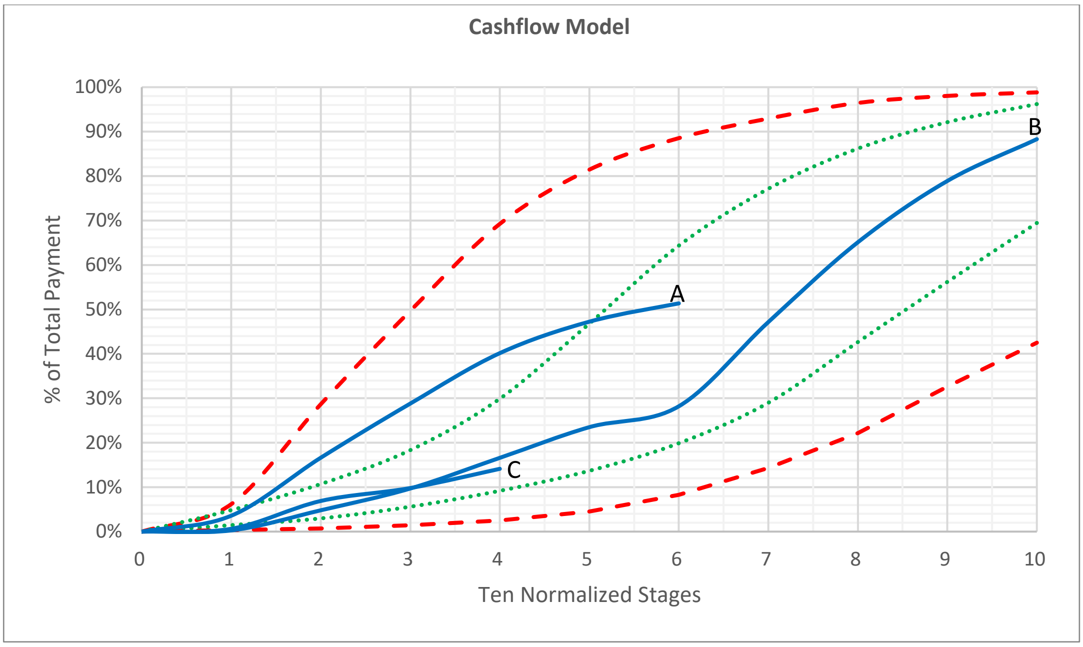

Figure 3: Demonstration of enhancement of performance

Figure 4 indicates the use of the cashflow model for the purpose of forecasting the cashflow performance of Projects A and C. Project managers and decision-makers can follow the model's expectations on cashflow performance as well as the project objectives to restructure work package schedules and predict acceptable cashflows accordingly. Whereas the solid lines show the actual cashflows, the continuing dashed lines show the forecasted cashflows of Projects A and C.

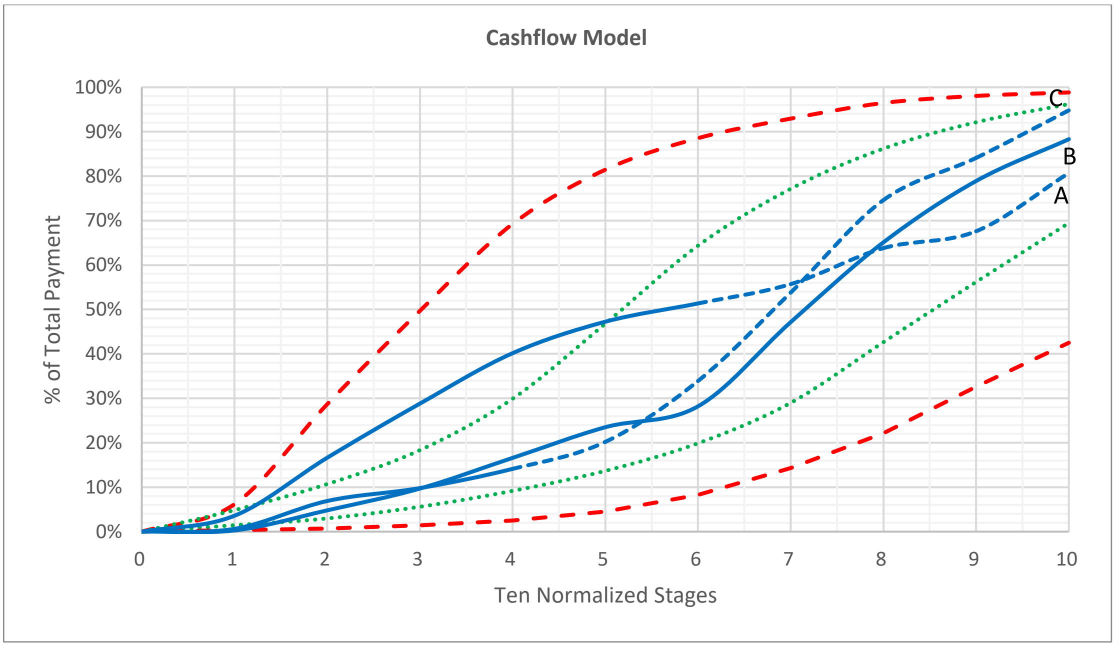

Figure 4: Demonstration of forecasting of performance

6 Conclusion and Limitations

Hospital projects are unique among the several types of construction projects because of their special characteristics and features. The development of hospital projects is very challenging and requires great project management efforts and decisions to be as much successful as several other types of construction projects. Therefore, there is a need to recommend methods to support project management efforts and decisions in achieving expected hospital project development goals. This study developed a cashflow model for monitoring the performance of hospital projects in the construction industry of Hong Kong. With the help of the innovatively combined normalization and percentile methods, the model is developed by using the monthly cashflow dataset of public hospital projects completed in the past 20 years. The model provides relevant alerts to help project managers and decision-makers realize three levels of cashflow performance i.e., green, yellow and red zones. While performance alerts in the green zone are probably fine, performance alerts in the yellow and red zones help in foreseeing existing or potential problems in ongoing hospital projects (i.e., time and/or cost overruns), guiding investigations to unearth any underlying causes of the problems, and providing early warning signals for corrective actions to be taken effectively in time. Theoretically, the study contributes to the knowledge bodies on hospital project success as well as performance modelling. Again, the introduction of the innovatively combined normalization and percentile methods is effective for solving similar research problems.

The findings of the study are relevant for a number of stakeholders and contribute to hospital project performance improvements. The findings would enhance the efforts of government agencies in formulating appropriate policies and legislations for implementing hospital projects. For instance, the Hong Kong government is implementing two 10-year hospital development plans to upgrade, expand and develop several healthcare facilities, amounting to about US$64 billion. As actual hospital projects are monitored with the cashflow model over time, the several monitoring results would build up into a powerful performance database to underlie the formulation of industry-wide policies and legislations to govern the development of hospital projects in Hong Kong. Also, the cashflow model would guide industry practitioners in planning and delivering hospital projects successfully. With sufficient understanding of the performance characteristics of the cashflow model, the practitioners could plan, structure and control work packages in a way that follows the typical cashflow pattern of hospital projects in order to increase the predictability of success. Besides, the hospital cashflow model would serve as a standard reference for researchers to develop different cashflow models for monitoring other unique project types such as railway, school, road, tunnel, pipeline, etc.

Though the study was undertaken successfully, there are some limitations that must be acknowledged. First, the sample size of the dataset is small due to the limited number of projects undertaken across the studied period and the filtering criteria employed. The sample size adequacy has a significant impact on the prediction accuracy of the model. Importantly, the sample size must be increased to a sufficient level to improve the accuracy of predictions. Second, over time, the database underlying the model development will outlive its relevance because of obsolescence. An out-of-date database cannot be significant for predicting cashflow performance at the current time. As such, the underlying database must be continuously refined and updated with only (new) project cashflows of the previous 20 years at any point in time. The normalization method must be followed to update the database and reconstruct the cashflow curves. Third, the model may be best suited for Hong Kong but not for other geographic jurisdictions. Hence, applying the model outside of Hong Kong should be done with caution in respect of the unique nature of hospital projects. Potentially, this model could serve as a good standard to guide the development of similar models in other jurisdictions for conducting comparisons and cross-learning. Fourth, monitoring hospital projects with the model is currently done manually. A digital platform that will allow for easy updates of the underlying database and resulting model as well as the monitoring of new projects will be a great push. Last, the construction industry is gradually embracing artificial intelligence (AI) to support the decision-making process of professionals in the Construction 2.0[1] era. As such, future research should consider incorporating AI into the cashflow model to unlock its best potentials in monitoring, enhancing and controlling hospital projects.

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