FORECASTING CAPABILITY OF A CONSTRUCTION ORGANISATION MODEL: 10 YEARS LATER

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The overall financial performance of construction organisations in Malaysia depends on the level of construction activity in the national economy. This in turn is a function of the state of the national economy which is cyclical in nature with a return period of approximately 10 to 12 years. This research seeks to test the validity of an organisation model first developed in 2001. In addition, the model is tested for its performance forecasting capability by comparing the forecast result generated from the model against the organisation's actual financial performance over the most recent economic cycle. This study shows that the accuracy of the model's forecast is dependent on regular updating of the model. It is found that with regular updates of the model's internal and external variables to reflect the strategic changes in the organisation and the state of the economy, a model with good forecasting capability can be produced. The validated model can be used to test the impact of proposed new strategies on the organisation's financial performance.

Keywords: construction organisation, modelling, system dynamics, validation.

INTRODUCTION

In Malaysia, the construction industry has consistently contributed between 3% to 5% of the nation’s total gross domestic product (GDP) and is one of the major movers of the national economy. The level of construction activity in Malaysia is determined by various factors such as the state of the economy and the government’s initiatives mainly through the various economic development plans. The effect of the economy on the construction industry can be seen in the GDP growth pattern of the construction industry which tracks that of the country’s economic cycle. The boom and bust cycle

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of the construction industry significantly affects the performance and survival of construction organisations in Malaysia particularly in periods of economic downturns.

Tang and Ogunlana (2003a) developed a system dynamics model to forecast the performance of a mid-range construction organisation subject to the effects of the economic cycles. The model (Figure 1) consists of five sectors representing aspects of the projects undertaken and the organisation's capability to deliver the projects successfully. The remaining four sectors deal with the financial aspects of the organisation particularly the impact of projects undertaken on the balance sheet. They also forecasted the performance of the organisation from 2001 to 2010 based on various proposed strategies (Tang and Ogunlana, 2003b).

Ten years (approximately the return period of the Malaysian economic cycle) has passed since the model was developed. This provides an excellent opportunity to compare the performance forecasted in 2001 against the actual performance of the organisation from 2001 to 2010. This study seeks to build confidence in the model as a tool for forecasting the performance of a construction organisation. In addition, this study also provides an understanding of the strategic changes in the organisation over the last decade and their impact on the organisation's financial performance.

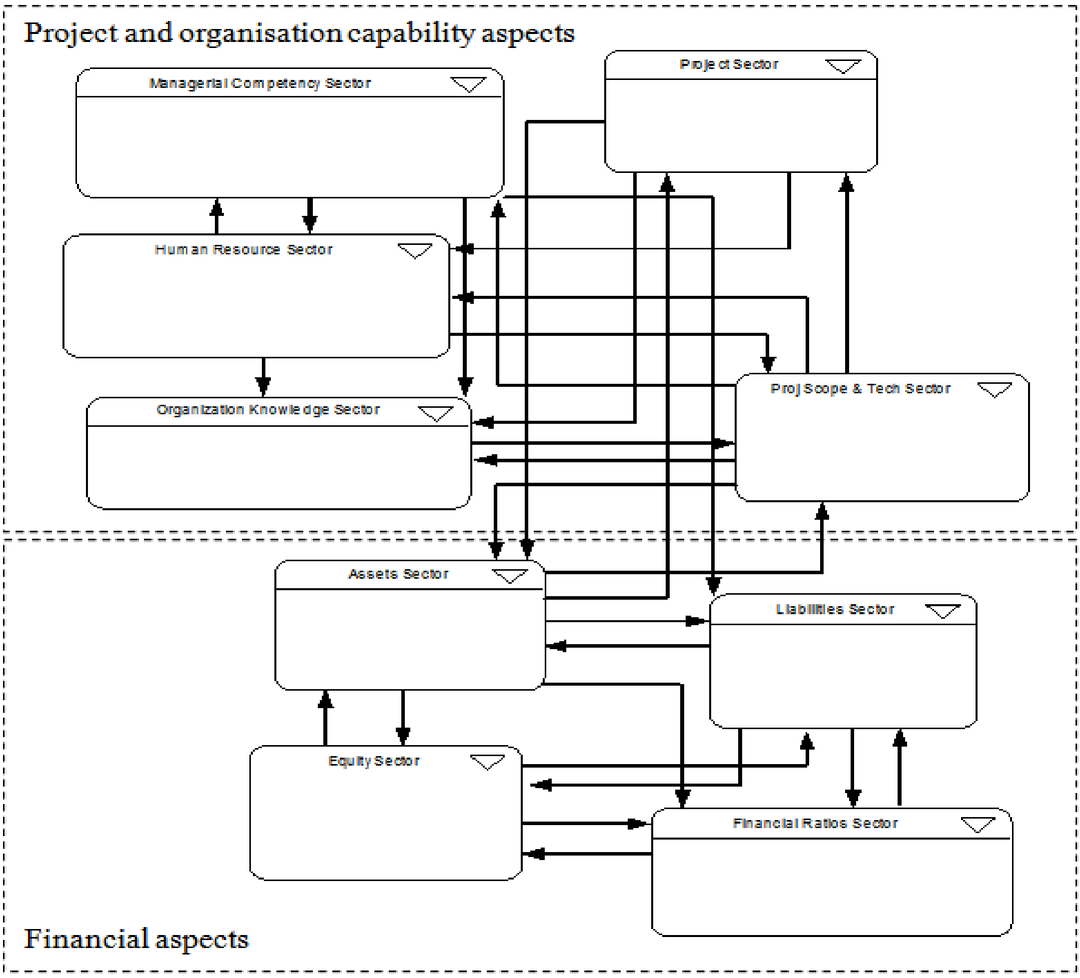

Figure 1: High Level Map of Organization Model

MODEL VALIDATION

Before testing a model's forecasting capability, the model has to be validated and this is an important element in system dynamics modelling. Generally, validity tests consist of structural and behavioural tests. Firstly, it is crucial to establish that the model is structurally valid before proceeding to validate the system's behaviour. The purpose of a structural validity test is to determine the adequacy of the model's structure in representing the actual structure (Barlas, 1989). Qurat-Ullah (2005) showed that structural validity tests are the core of system dynamics modelling and have a temporal precedence over behaviour validity test. There are several tests used to structurally validate a system dynamic model, as described by Forrester and Senge (1979) such as boundary adequacy test, structural verification test, parameter verification test, dimensional consistency test, and extreme conditions test. In recent years, structural validation tests have been divided into direct structural tests and structure-oriented behavioural tests (Barlas, 1994). Once the confidence level from structural validation is achieved, behavioural tests are conducted to determine how accurately the model reproduces major behaviour patterns of the real system. If a model is built to a high confidence level structurally, and yet produces a weak behaviour pattern, it is an indication of a possible result of misrepresentation of some parameter values or exogenous input in the model.

Historical fit is one of the tests found to be important in building confidence in system dynamic models (Sterman, 1984). Forrester and Senge (1979) also showed several behavioural validation tests which include behaviour reproduction test, behaviour prediction test, behaviour anomaly test, family member test, surprise behaviour test, extreme policy test, boundary adequacy test as well as behaviour sensitivity test.

In this study, the main test used is the behavioural prediction test, i.e. the ability of the model to replicate the actual behaviour of the system. Sensitivity analysis is an important tool used to evaluate the reliability and robustness of the model output (Hekimoglu & Barlas, 2010). The importance of sensitivity analysis in system dynamics is prominent due to the presence of assumptions and uncertainty in the model. According to Forrester and Senge (1979), parameter sensitivity testing is capable of not only demonstrating the robustness of a model's behaviour but also an important test in policy testing.

RESEARCH OBJECTIVE AND METHODOLOGY

This study is a continuation of Tang and Ogunlana's (2003a & 2003b) earlier work on the modelling of a construction organisation's dynamic performance under cyclic economic conditions. The main aim of this study is to determine the reliability of the system dynamics model as a forecasting tool in predicting organisational financial performance. The "classic system dynamics method" discussed by Saeed (1995) is adopted in this study. In addition, the construction organisation model used in this study is adapted from Tang and Ogunlana's model.

Using the empirical evidence which consists of a collection of historical data from the construction market and the construction organisation particularly through the organisation's annual reports over the period between 2001 and 2010, a reference mode as represented by the financial performance of the company and the economy can be formulated to validate the model. The causal relation of key elements in the construction organisation is then modelled as the dynamic hypothesis. Figure 2 shows the causal loop diagram for the organisation's financial balance sheet which forms one of the feedback diagrams in this model. Subsequently, this is converted into a formal model using a system dynamics software called STELLA Research which is then tested and validated for its confidence level by comparing the result obtained from the model against the reference mode. If the model fails the validity tests, the dynamic hypothesis is rechecked and changes are made to the model. This is a iterative process until the model is validated.

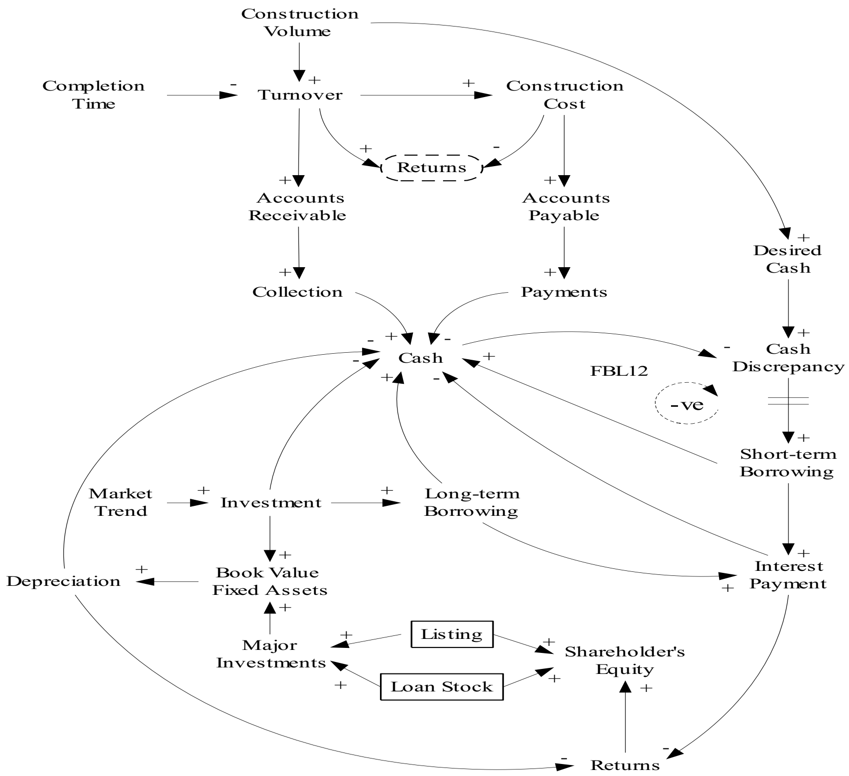

Figure 2: Financial Balance Sheet Feedback Loop Diagram

The model's structural validity was tested by using tests proposed by Qurat-Ullah (2005) and Forrester and Senge (1979). However the extreme condition testing was not carried out, as it is similar to the sensitivity analysis carried out in the later part of this study. Since the model simulated displayed a transient and highly non-stationary behaviour with sudden boom and bust pattern, it was not practical to use statistical tools to perform behavioural validation. Therefore graphical/visual measure was adapted to validate the model. The behaviour reproduction test recommended by Forrester & Senge (1979) was principally used to validate the model. Results generated from the simulated run of the original model are tested against data collected from historical data or the reference mode using the graphical/visual method.

ORIGINAL MODEL FORECASTING PERFORMANCE

Figure 3 and 4 graphically display the model forecast of the construction market and market trend of the original model compared with data from 2001 to 2010. The data showed a timeline from the years 1988 to 2010 with the time frame of 2000 until 2010 being the forecasted market. Visual inspection of the graphs indicate that the original model had underestimated the growth of the construction market. However, the market trend shows a similar pattern when compared to the historical data. This indicate that even though the forecasted performance of the construction market is lower than that of the actual construction market, it displays a similar pattern of between 10 to 11 year economic cycle as postulated by Tang and Ogunlana (2003a).

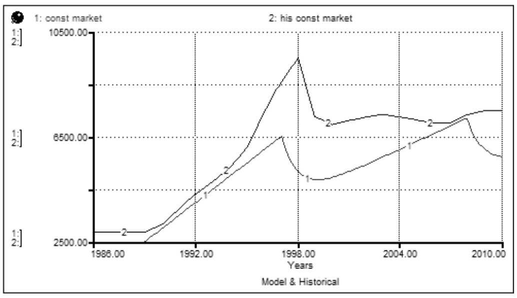

Figure 3: Construction Market

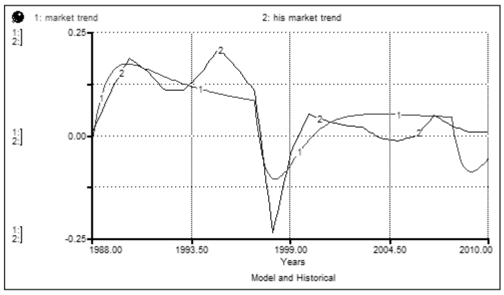

Figure 4: Construction Market Trend

Due to the underestimation of the size of construction market, the behaviour of the annual turnover, net profit after tax and total asset showed large discrepancies when compared to the historical data. Consequently, a large difference in magnitude and direction of change in the behaviour is observed in the financial ratios used to measure the organisation’s performance. Based on the visual evaluation of the results, it shows that without any model update, the model do not produce a good behavioural fix. This can be observed from the high discrepancies in behavioural pattern and amplitude of key variables which suggest that confidence level for the forecast model is low. The six financial ratios used to measure performance did not perform well in the behavioural validity test except for return on equity and return on total asset with marginally acceptable results. This is expected as ten years is too long a period for forecasting to be carried out accurately, due to the many external and internal variables affecting the construction environment and the construction organisation respectively. All the unforeseen changes in these variables make long-term forecasting difficult.

MODEL ADJUSTMENT AND UPDATES

Adjustments and updates are made to the original model to better reflect the external and internal changes that affect the organisation over the past 10 years. The model is updated with the actual market conditions from 2001 to 2010 and organisation strategic changes identified from reviewing the organisation's annual reports spanning the same duration. These include:

Actual construction market condition

The main external factor affecting the organisation performance is the state of the construction market which is a function of the overall national economy. From historical data, the construction market is at approximately RM2 billion for the year 1988 and remained at a steady state. The construction market was originally simulated in Tang and Ogunlana's model to grow at a constant rate of twenty five percent annually with a slump of forty percent in 1997 due to the Asian financial crisis and another slump forecasted around 2007, which incidentally coincide the global financial crisis in 2008. However, the actual growth in subsequent years after 1997 was stronger than forecasted partly due to the development of Putrajaya as the new administrative centre. Other major exogenous factors affecting the construction market in the last decade were the 9/11 incident in 2001, the oil inflation in 2005 and the sub-prime crisis during 2008 which caused the construction market to contract by ten percent during each major slowdown. The model is updated by making the necessary changes to construction market converter (P1) as shown in Figure 5.

Regional expansion

The organisation expanded their project scope overseas and secured a project in Thailand in 2006 with the value of RM100 million. This is represented by regional market converter (P2) in Figure 5. The expansion of construction work to the regional market increases the level of complexity faced by the organisation. This is in line with the recommendation given by Tang and Ogunlana (2003b) which suggested this strategy as a means of reducing the risk of exposure to Malaysia's economic cycle.

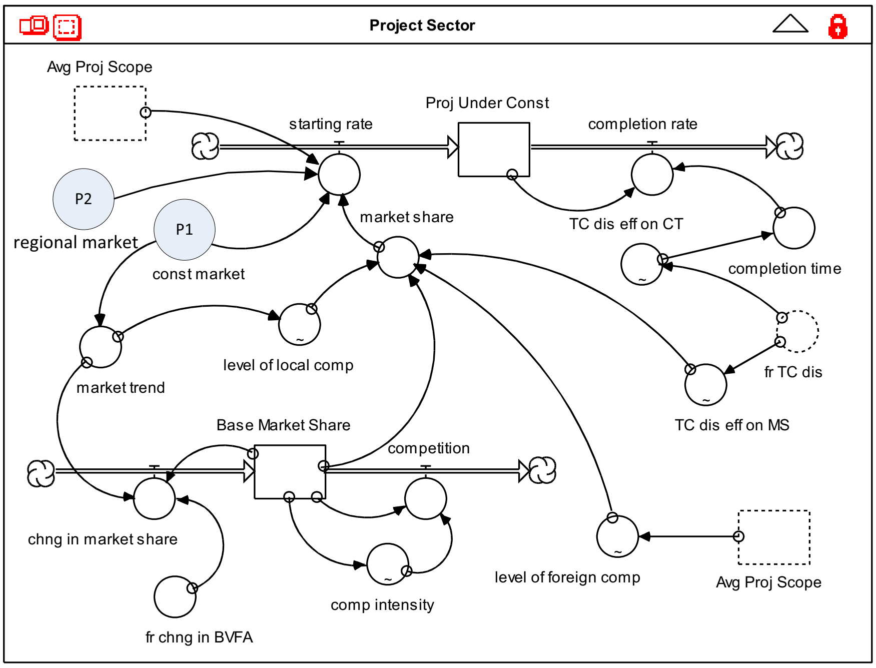

Figure 5: Updated Project Sector

Issuance of Bonds

In the year 2002, RM62 million worth of ABBA bonds were issued by the construction organisation which matured in mid-2008. This increased the level of total liability in the organisation. This is a strategic decision of the organisation to increase its financial capability.

Effect of technical capability discrepancy on project scope

One major adjustment to the original model is on the relationship between the organisation's technical capability and the project scope. Initially, it is suggested that the lack of technical capability would limit the organisation's ability to take on larger scale projects. However, the revalidated model shows that project scope actually grew despite the lack of organisation capability. This suggests that the size of projects undertaken by the organisation is not constrained by its technical capability. This issue will be discussed further as part of the research findings.

VALIDATION OF UPDATED MODEL

The updated model of the construction organisation is retested for its validity through structural and behavioural validations. The structural validation test is conducted based on the methodology discussed earlier. No illogical parameters or equation is found present in the model. Furthermore, boundary conditions as well as parameters of the model are satisfied. This demonstrates that the model is valid structurally with acceptable confidence level.

The updated model successfully simulated the construction market and the market trend in that it displays almost identical behaviour to the actual market conditions. The annual turnover and net profit after tax displayed patterns and behaviours similar to the real system. However, both the modelled graphs showed a slightly higher magnitude. The total asset and shareholder's fund graphs demonstrate good resemblance to the historical data with minimal deviations. The financial ratios are represented by Figure 6 to Figure 11 which demonstrate good behavioural similarity to the actual system. However, Figure 8 and Figure 9 which represent the efficiency ratios showed the model's lack of ability to duplicate the erratic changes in the historical data. Minor variances in the graphical result throughout can be caused by random occurrences as well as time deviation in reporting the financial activities of the construction organisation. Reproduction of sudden fluctuation in the time series variables also appear to be difficult as system dynamics models produce a more gradual increment and decrement.

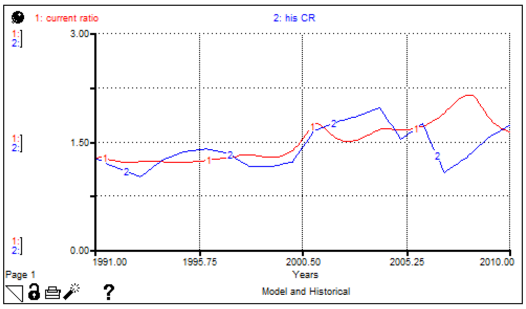

Figure 6: Current Ratio

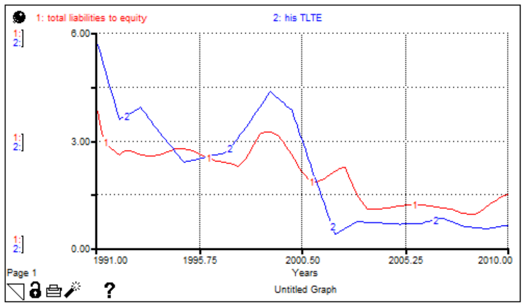

Figure 7: Total Liabilities to Equity

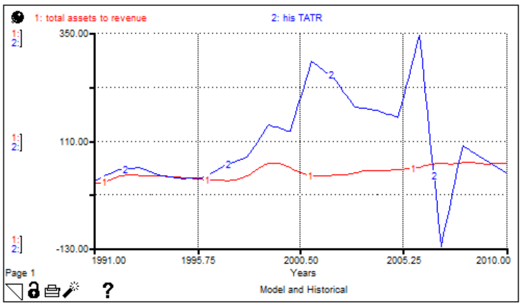

Figure 8: Total Assets to Revenue

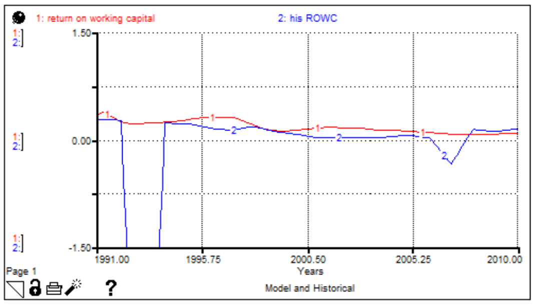

Figure 9: Return on Working Capital

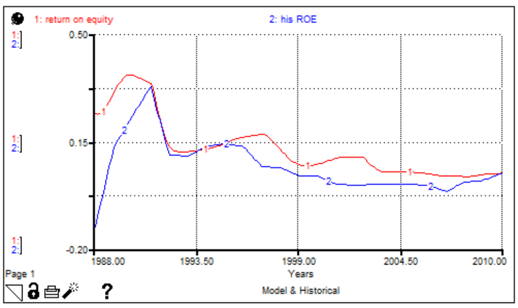

Figure 10: Updated Return on Equity

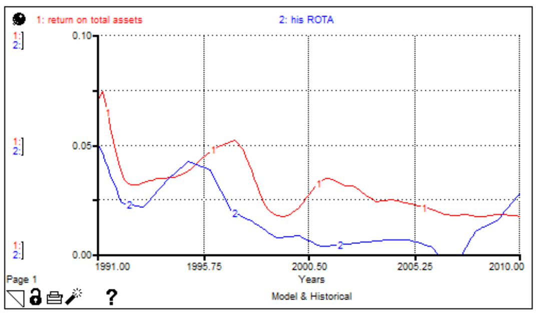

Figure 11: Updated Return on Total Asset

In summary, the key variables in the model such as construction market, construction market trend, annual turnover, total asset and shareholder's fund demonstrated similar behavioural pattern when compared with actual historical data. The six financial ratios used to measure the organisation's performance are reasonably capable of emulating the actual system, with the exception of the efficiency ratios. Generally the behavioural validity test validates the model with a good level of confidence. The results obtained from the sensitivity analysis of stock and converters indicate that parameters with high sensitivity are fraction rolling fund, project under construction and time to train. Other sensitive parameters are technical capabilities discrepancy effect on completion time, project scope and market share. The results of the sensitivity analysis demonstrate the robustness of the model. Moreover, all the variables with high sensitivity can be used as important leverage points for the formulation and design of improvement policies.

MAIN FINDINGS

Firstly, even though the system dynamics model is capable of reasonably replicating real life dynamic behaviour of the construction organisation, unforeseen and unpredicted variables make forecasting long-term behaviour of a construction organisation difficult. This study demonstrates that using system dynamics for performance forecasting has its limitations. Good understanding of the construction industry and the construction organisation is needed in formulating a good model. However, it is found that with updates of the external and internal variables of the organisation, a model with fairly good confidence can be produced. This suggests that with periodical updates to reflect internal strategic changes as well as changes in the external environment, a good forecasting model can be developed. It should be noted that long term forecasting is fraught with high levels of uncertainty which make accurate modelling difficult. Therefore, a shorter forecasting horizon is strongly recommended. It is recommended that the model should only be used for testing medium term strategies where the construction market can be forecasted more accurately.

Secondly, the lack of technical capabilities within does not limit the organisation's ability to take on projects of greater complexity. Instead, financial capability is the main determinant in the selection of projects undertaken by the organisation. The lack of technical capabilities could however affect the expansion of an average project size, due likely to an increase in reworks or variation orders. The lack of technical capabilities is a growing problem in the industry. Ibrahim *et al.* (2010)'s study of the Malaysian construction industry showed that there is a shortage of technical, managerial and skilled personnel in the country and therefore identified human resources as one of the key challenges faced by the industry. Workers need to be trained in order become competitive and capable, as well as to enhance operational performance. Similarly, Tabassi and Abu Bakar (2009) found that with proper human resource management, low quality construction, additional project cost and projects delay could be minimised. This finding challenges the dynamic hypothesis of the original model which states that the level of technical capabilities in a construction organisation limits the size of projects undertaken. Such findings are not unusual as the process of model building often results in the organisation learning about the flaws in their earlier assumptions. (Senge, 1990)

Thirdly, the expansion of the organisation to Thailand in 2006 provided an additional income stream for the construction organisation that helped mitigate against the economy downturn in 2008. Managing construction projects in foreign country increases operations complexity and cost due to the distance and the difference in both culture and practice. Overseas project are generally more risky (Zhi, 1995). However, this study suggests that contracting overseas project could be a strategic move for local construction organisations to mitigate against the risk of downturn in the national economy and by extension the national construction market.

CONCLUSIONS

The construction industry is a very competitive industry and during recent years, the construction industry in Malaysia has been in a slump and this has negatively affected many construction organisations. Therefore it is important for construction organisations to improve their performance and competitiveness to survive periods of economic downturn. Tang and Ogunlana (2003b) demonstrated how system dynamics model of organisations could be used to help its senior management test the impact of proposed new strategies such as implementing new management information system, adopting a new quality system or expansion to regional market, on the organisation's financial performance subject to the impacts of the economic cycle. However, this is dependent on the capability of the model to forecast future performance. Ten years or one economic cycle has passed since the model was first developed and the historical data available was used to test the validity of the model and its capability to forecast future performance by comparing the organisation's actual performance with the model's forecast. The study shows that with regular updates of the organisation's internal variables and external market variables, a model with good short to medium term forecasting capability can be produced. The validated model can be used to test the impact of proposed new strategies on the organisation financial performance.

REFERENCES

Barlas, Y. (1994) Model Validation in System Dynamics. "1994 International System Dynamics Conference", 1-10.

Barlas, Y. (1989) Multiple Tests for Validation of System Dynamics Type of Simulation Models. "European Journal of Operational Research" **42**, 59-87.

Chan, A. C. (2004) Key Performance Indicators for Measuring Construction Success. "Benchmarking: An International Journal", **11**(2), 230-221.

Chang, C. L., Ogunlana, S., & Saeed, K. (1991) Construction Project Management: A system dynamic approach. "Proceedings of the 1991 International System Dynamics Conference", Asian Institute of Technology, Bangkok, Thailand, 108-115.

Forrester, J. W., & Senge, P. M. (1979) Test for Building Confidence in System Dynamic Models. "System Dynamics Group", 1-40.

Hekimoglu, M., & Barlas, Y. (2010) Sensitivity Analysis of System Dynamics Models by Behaviour Pattern Measures. "28th International Conference of the System Dynamics Society", 1-31.

Ibrahim, A. R., Roy, M. H., Ahmed, Z., & Imtiaz, G. (2010) An investigation of the status of the Malaysian construction industry. "Benchmarking: An International Journal", **17**(2), 294-308.

Mawdesley, M. j., & Al-Jibouri, S. (2010) Modelling construction project productivity using system dynamics approach. "International Journal of Productivity and Performance Management", **59**(1), 18-36.

Ogunlana, S., Li, H., & Sukhera, F. (2003) System Dynamics Approach to Exploring Performance Enchancement in a Construction Organisation. "Journal of Construction Engineering and Management", 528-536.

Park, M., Ji, S.-H., Lee, H.-S., & Kim, W. (2009) Strategies for Design-Build in Korea Using System. "Journal of Construction Engineering and Management", 1125-1137.

Pena-Mora, F., & Li, M. (2001) Dynamic planning and control methodology for design/build fast-track construction projects. "Journal of Construction Engineering and Management", 1-17.

Qurat-Ullah, H. (2005) Structural validation of System Dynamics and Agent-Based Simulation Models. "Proceedings of 19th European Conference on Modelling and Simulation", Riga, Latvia.

Roberts, M., & Latorre, V. (2009) KPIs in the UK's Construction Industry: Using System Dynamics to Understand Underachievement. "Revista de la Construcción", **1**(8), 69-82.

Saeed, K. (1995) The Organisation of Learning in System Dynamics Practice. "Proceedings of the System Dynamics' 95 Conference", 235-245.

Senge, P. (1990) "The Fifth Discipline: The Art and Practice of Learning Organisation". Currency.

Sterman, J. D. (1984) Appropriate Summary Statistics for Evaluating the Historical Fit of System Dynamics Models. "DYNAMICA", **10**, 51-65.

Sterman, J. D. (1992). "System dynamics modeling for project management." < http://web.mit.edu/jsterman/www/SDG/project.pdf> (Assessed: Aug 3, 2011)

Tabassi, A., & Abu Bakar, A. (2009) Training, Motivation and Performance: The Case of Human Resource Management in Construction Projects in Mashhad, Iran. "International Journal of Project Management", **27**(5), 417-480.

Tang, Y., & Ogunlana, S. O. (2003a) Modelling the dynamic performance of a construction organisation. "Construction Management and Economics", **21**(2), 172-136.

Tang, Y., & Ogunlana, S. O. (2003b) Selecting superior performance improvement policies. "Construction Management and Economics", **21**(3), 247-256.

Zhi, H. (2005) Risk management of overseas construction projects. "International Journal of Project Management", **13**(4), 231-237.