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RESEARCH ARTICLE

Understanding the Performance of Construction Business: A Simulation-Based Experimental Study

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Abstract

Higher failure rates of construction business have been observed as a recurring phenomenon in the construction industry. This research focuses on the causes behind a range of performance modes of construction business. The growth and capacity under-investment archetype has been used as the main systems archetype to develop a causal structure for understanding the business performance. A system dynamics model was developed to create a simulation platform for the causal structure. A context of a typical small and medium construction company has been used in the simulation model. This research considered and experimented with a set of selected managerial policies and practices that can lead the construction business to failure, sustenance, or growth. In order to achieve the expected growth or sustenance, it is found that a certain level of balance needs to be secured on how much emphasis is to be given to win new projects, how much profit margins to work with, and how much capacities to be arranged and deployed for project operations, management, and execution.

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Keywords

Construction Business Performance; Project; Finance; Capacity; System Dynamics; Simulation Experiment

Introduction

In any progressive economy, it can be observed that the registered construction firms would be remarkably large in number. The indicated volume of construction work in terms of their monetary value is perceived to be huge, and at the same time, barriers to entry in the market are generally low for construction firms (Dikmen et al., 2010; CIDB, 2006; Kenley, 2003). Probably because of these reasons, entrepreneurs, especially the small and medium ones, get attracted to the construction business. Another pattern that can be observed in any construction industry is that the small and medium-sized firms would be relatively more in number in comparison to the large ones, whereas the output generated by the few large ones would be generally higher than the collective output of the small and medium ones (Ofori, 1990). For example, the proportions of SMEs (with up to 250 employees and £50m annual turnover) in the UK construction sector have been consistently high over the last 20 years (ONS, 2018). Because of the sheer number of SMEs, their collective contribution to the construction industry and the overall economy is quite significant. However, another set of observations indicates that these small and medium construction companies are facing many challenges in sustaining their business in the industry. The failure and bankruptcy rates of such companies are very high, irrespective of whether they are in the developing (Enshassi, Al-Hallaq and Mohamed, 2006; Abu Bakar, 1993) or developed economy (Wood, 2015; Russel and Cassey, 1992). For example, the insolvencies statistics in 2019 in the UK recorded that the highest number of new company insolvencies was in the construction industry with 3,198 underlying insolvency volumes, which had increased by 2.2% when compared with the 12 months ending Q3 2019 (The Insolvencies Service, 2019). Likewise, the construction industry in Australia accounted for 20-25% of all insolvencies, with the proportion of 8-10% contribution in the GDP (Murray, 2018).

A sizable volume of literature on the performance of construction firms dealt with the issues of failure (Holt, 2013; Enshassi, Al-Hallaq and Mohamed, 2006; Arditi, Koskal and Kale, 2000; Kale and Arditi, 1998; Kangari, 1998; Russell and Casey, 1992), whereas few others observed from the side of growth as well (Abu Bakar, et al., 2012; Punwani, 1997; Abu Bakar, 1993). This paper focuses on the issue of growth and failure of construction firms, particularly by exploring the underlying causes in the domain of construction business management. Furthermore, in this research, the growth and failure of construction firms are not taken as isolated performance patterns, but they are considered as the possible outcomes at the two sides of the performance continuum. It means that there could be different possible performance outcomes in between the two extremes of absolute success and hopeless failure.

The aim of this research is to develop an understanding of the underlying causes of different performance modes of construction firms. A simulation model was developed to explain a range of performance outcomes of construction firms. The system dynamics modelling approach (see Sterman (2000) for detailed explanation) has been used to develop the model with a set of causal structure subsuming the context of, and the policies and practices in construction business. The findings of the simulation experiments with the model have been reported as the conclusions of this research.

Literature Review

Performance of general business or construction firms could be conceptualised and understood from different vantage points considering the very purpose of the use of the construct of performance as such. For instance, Deng and Smyth (2013a) summarised their literature review in understanding the performance

of construction firms and reported that there could be four broad perspectives considered by researchers for: (i) clarifying the concept of firm performance, (ii) identifying the practical issues with specific concept of performance, (iii) benchmarking a firm's performance, and (iv) investigating the determinants of performance through modelling, comparison, or prediction. The same authors in another work (Deng and Smyth, 2013b) pointed that the majority of organisational studies in construction firm rely on cross-sectional analysis and very few considered longitudinal studies whereas "*explicitly exploring the performance dynamism is crucial for performance measurement and management of construction companies in the long run*". This research, as it will be explained in the conceptual framework section, uses the formal modelling approach of understanding the performance of construction firm in order to explore the "performance dynamism".

In another set of the literature, construction business performance is generally investigated in terms of the causative factors that lead to failure or growth of business. These factors include the external forces in industry, and internal situational and management-related factors, most of which are associated with the management of finance and cash flow (Jang, Jiong and Cho, 2020; Abu Bakar, et al., 2012; Arditi, Koskal and Kale, 2000; Kale and Arditi, 1998; Abu Bakar, 1993; Hillebrandt and Cannon, 1990; Kangari, 1988). These studies do provide insights into the factors and their respective influence on the failure or growth of construction firms. However, it is generally observed that individual factors would not affect the entire business unilaterally and independently – the factors are generally inter-related and interdependent (Rice, 2016). Therefore, there is a need for integrative or systemic inquiry, and this research attempts to fulfil this need.

Understanding the various aspects of construction firm performance could help address a certain kind of research questions. However, going a little further, a different set of review is needed in order to understand why firms perform as they perform or why some firms are successful while others are not in the similar business environment. The theories of the growth of firm could be a right domain to look into because growth is generally an important performance outcome (Stevenson and Jarillo, 1990), although it is not necessary that growth will bring in perceptively the better performance outcome. Greiner (1972) stated that businesses grow in five subsequent phases from growth through creativity to growth through direction, through delegation, through coordination, and growth through collaboration. Some economic theorists posit that there could be two kinds of business growth: organic and inorganic (through mergers and acquisitions), and the growth pattern of SMEs would dominantly be the organic one (Davidsson and Delmar, 1998). The frequently used measure of growth are profit, units of output, sales volume and market share (Delmar, 1997). These measures are interdependent but the actual nature of interdependencies as observed in empirical research are still vague and inconsistent (Machek and Machek, 2013; Garnsey, Stan and Heffernan, 2006). Moreover, firm growth is a multi-dimensional, heterogeneous and complex phenomenon (Leitch, Hill and Neergaard, 2010), and the internal dynamics have largely been unclear for most growth studies (Freel, 2000).

There are a few notable studies in which the approach of system dynamics (SD) has been used to study the competitiveness and performance of construction firms. Dangerfield, Green and Austin (2010) and Gilkinson and Dangerfield (2013) assessed the utility of the SD modelling approach to understand the dynamics of the competitiveness of construction firms. Ogunlana, Li and Sukhera (2003) developed an SD model to derive a set of broader strategic policies to enhance the performance of a construction firm. Tang and Ogunlana (2003a) developed another set of SD model to replicate a level of operational details of a construction firm, and using the same model Tang and Ogunlana (2003b) explored another set of broader strategic policies to enhance the performance of the construction firm. The models reported in the above last three SD studies explored the policies such as forming joint ventures, development of management information systems, establishing construction industry development board, implementing quality assurance systems, and expanding the regional market for construction firms. These policy options, in essence, include

a mix of broad and exogenous courses of policies. There is a need for a more finely operationalized model to explore a bit more realistic and endogenous policies to be used by construction firms.

Yildiz, Dikmen and Birgonul (2020) presented an extensive exercise in developing dynamic strategy maps in order to strategically plan and manage the performance of a Turkish international construction company. A risk/return analysis was done with the selected operational strategies such as increasing profit margins, winning new projects, managing stakeholders and strengthening human and technical resources capabilities. The SD approach and findings in the study were however reported implicitly. In this paper, emphasis is given in presenting the conceptual and then simulation model explicitly with the underlying concepts, assumptions, and even the model equations. The developed model attempts to capture the comprehensive understanding of construction business with a closer insight into the functional and operational essence.

Conceptual Framework

The conceptual framework used in this paper has been taken from the authors' previous work presented in Bajracharya, et al. (2018). The work developed a qualitative systems thinking model that can explain a range of performance modes of construction firms in SME category. The main conceptual basis of the work is the limits to growth archetype, particularly the one that explains the growth and capacity underinvestment (Sterman, 2000; Senge, 1990). The archetype explains the phenomenon whereby the growth (in business) itself creates limiting situations, and if the limiting forces are stronger, then the growth could get pulled down to the situation of decline and deterioration. The growth and capacity underinvestment archetype (a version of it as presented in Figure 1) explains that the efforts for performance and growth essentially need capacity resources, and more efforts mean more consumption of capacity. If the consumption of capacity is overlooked or if there is reluctance/ignorance in making a timely investment to arrange capacity to move in sync with the growth, then the available capacity would get strained. The strained capacity creates a deficit situation in the capacity to put effort. This would affect the performance of the company, and if the performance gets persistently affected, then it would pull down the growth itself. The whole process is dynamic in essence, and the challenge is to manage the changing growth and performance level with the changing capacity availability.

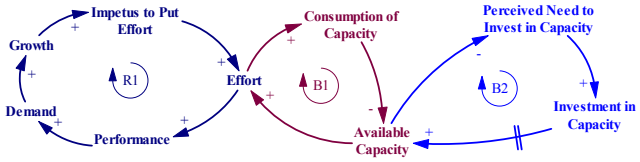

Figure 1. The Growth and Capacity Underinvestment Archetype

The concept of the archetype could be compared with the various connotations of accompanying constraints or risks of the growth of firm as mentioned in the mainstream management literature. Referring to Penrose's seminal work on the theory of the growth of the firm (Penrose, 1959 and 1995), the rate of growth could be constrained due to the lagged process of acquiring and accumulating sufficient levels of managerial knowledge and expertise, which Barringer and Jones (2004) considered as the managerial capacity problem. Hess (2010) pointed the risks of growth in terms of the over consumption of capabilities and competencies of the company, and the stressed internal operations that can potentially weaken the existing business. According to Nicholls-Nixon (2005), if the growth is fast, it would add and create managerial complexity that requires organisational adaptation. Hambrick and Crozier (1985) found that rapid growth could create serious issues of pressure and adaptability on the side of employees in the

organisation. The stressed and over-consumed capacity could eventually drive the organisation into chaos zone triggering the crisis and even the situation of growth reversal (Garengo and Bernardi, 2007; Covin and Slevin, 2000).

The essence of the various connotations of the implications of growth are in fact succinctly captured by the growth and capacity underinvestment archetype. Senge (1990) developed the concept of the archetype, and Morecroft (2015) elaborated it at a greater length taking a reference to Forrester's market growth model (Forrester, 1968). Sterman (2000, pp. 605 and 606) asserted that "*Though based on the case of a particular firm, the (market growth) model is quite general and its lessons apply to growing organizations in any industry*". Using the concept of the market growth model, Morecroft (2015) analysed the performance modes of a high-tech manufacturing company with different executive policies used in the specific context of the company. Bajracharya, et al. (2018) developed an adapted version of the concept of growth and capacity underinvestment archetype in the context of the construction business. Figure 2 presents a slightly modified version of the archetype model, and this particular model is the main conceptual basis of this research.

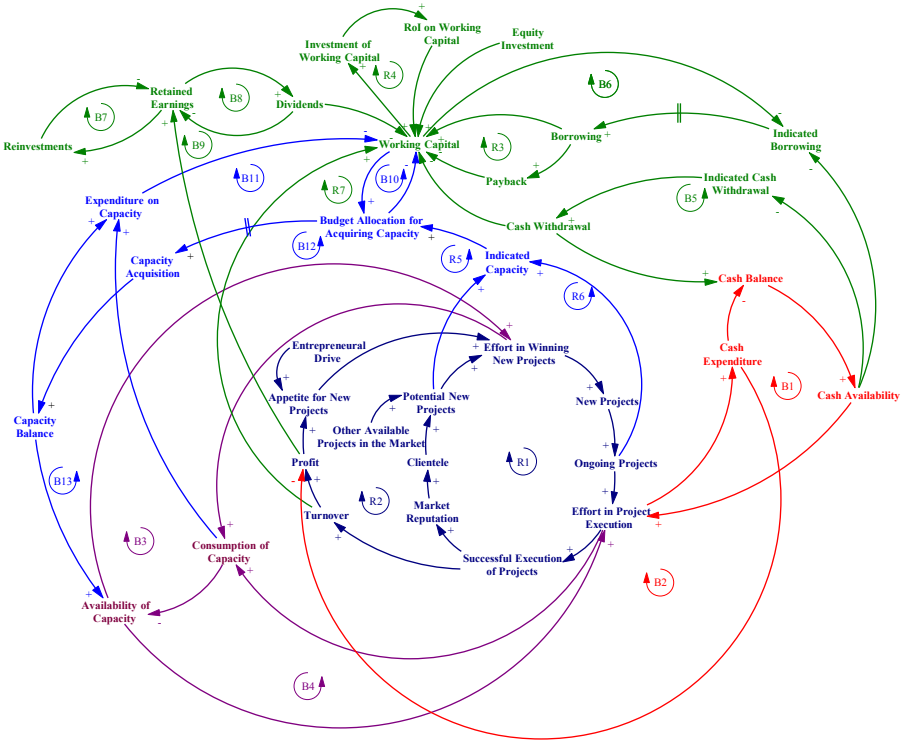

Figure 2. The Conceptual Model

There are altogether eight reinforcing (indicated by Rs) and twelve balancing (indicated by Bs) feedback loops (FBLs) identified in the model presented in Figure 2, and they are divided into six different categories (see Table 1). The first category includes two reinforcing FBLs (R1 and R2) that explain the main growth or deterioration processes that could take place in construction business. The first reinforcing FBL R1 explains a growth process based on a better market reputation due to the track record of successful execution of projects. Better market reputation provides a broader clientele which would increase the positive network externalities (Hellofs and Jacobson, 1999; Yoon, Guffey and Kijewski, 1993) and thus the prospect of potential new projects (Nieto-Morote and Ruz-Vila, 2012; Ng, Tang and Palaneeswaran, 2009), and such prospects encourage business owners to put more effort in winning new projects. The won new projects would then be implemented as ongoing projects, and more successful execution of ongoing projects means

Table 1. Feedback Loops in the Conceptual Model

1. The Main Growth or Deterioration
   a. The track record and market reputation loop (R1): *Effort in Winning New Projects →+ New Projects →+ Ongoing Projects →+ Effort in Project Execution →+ Successful Execution of Projects →+ Market Reputation →+ Clientele →+ Potential New Projects →+ Effort in Winning New Projects*
   b. The turnover and profit loop (R2): *Effort in Winning New Projects →+ New Projects →+ Ongoing Projects →+ Effort in Project Execution →+ Successful Execution of Projects →+ Turnover →+ Profit →+ Appetite for New Projects →+ Effort in Winning New Projects*
2. The Limiting Effect due to the Cash Consumption
   a. The limiting effect due to cash expenditure for the Effort in Project Execution (B1): *Effort in Project Execution →+ Cash expenditure → – Cash Balance →+ Cash Availability →+ Effort in Project Execution*
   b. The limiting effect due to cash expenditure for the Effort in Project Execution and constrained Profit (B2): *Effort in Project Execution →+ Cash expenditure → – Profit →+ Appetite for New Projects →+ Effort in Winning New Projects →+ New Projects →+ Ongoing Projects →+ Effort in Project Execution*
3. The Limiting Effect due to the Capacity Consumption
   a. The limiting effect due to consumption of capacity for the Effort in Winning New Projects (B3): *Effort in Winning New Projects →+ Consumption of Capacity → – Availability of Capacity →+ Effort in Winning New Projects*
   b. The limiting effect due to consumption of capacity for the Effort in Project Execution (B4): *Effort in Project Execution →+ Consumption of Capacity → – Availability of Capacity →+ Effort in Project Execution*
4. Managing the Cash and Finance
   a. Managing the Cash Balance by withdrawing from the Reserve of Working Capital (B5): *Cash Balance →+ Cash Availability → – Indicated Cash Withdrawal →+ Cash Withdrawal →+ Cash Balance*
   b. Managing the Reserve of Working Capital by Borrowing (B6): *Reserve of Working Capital → – Indicated Borrowing →+ Borrowing →+ Reserve of Working Capital*
   c. Arranging Reinvestment from the Retained Earnings (B7): *Reinvestment → – Retained Earnings →+ Reinvestment*
   d. Maintaining the Retained Earnings with Dividends for Shareholders (B8): *Retained Earnings →+ Dividends for Shareholders → – Retained Earnings*
   e. The profit and its reinvestment effect (B9): *Profit →+ Retained Earnings →+ Dividends→– Reserve of Working Capital →+ Budget Allocation for Acquiring Capacity →+ Capacity Acquisition →+ Capacity Balance →+ Availability of Capacity →+ Effort in Project Execution →+ Successful Execution of Projects →+ Turnover →+ Profit*
5. Managing the Capacity
   a. Budget Arrangement for Acquiring Capacity (B10): *Reserve of Working Capital →+ Budget Allocation for Acquiring Capacity → – Reserve of Working Capital*
   b. Managing the expenditure to maintain the Capacity Balance (B11): *Capacity Balance →+ Expenditure on Capacity → – Reserve of Working Capital →+ Budget Allocation for Acquiring Capacity →+ Capacity Acquisition →+ Capacity Balance*
   c. Managing the expenditure due to Consumption of Capacity for the Effort in Winning New Projects (B12): *Consumption of Capacity →+ Expenditure in Capacity → – Reserve of Working Capital →+ Budget Allocation for Acquiring Capacity →+ Capacity Acquisition →+ Capacity Balance →+ Availability of Capacity →+ Effort in Winning New Projects →+ Consumption of Capacity*

Table 1. continued

d. Managing the expenditure due to Consumption of Capacity for the Effort in Project Execution (B13): *Consumption of Capacity →+ Expenditure in Capacity → – Reserve of Working Capital →+ Budget Allocation for Acquiring Capacity →+ Capacity Acquisition →+ Capacity Balance →+ Availability of Capacity →+ Effort in Project Execution →+ Consumption of Capacity*
6. Other Reinforcing Processes in the System
a. The potential debt trap (R3): *Indicated Borrowing →+ Borrowing →+ Payback → – Reserve of Working Capital → – Indicated Borrowing*
b. The gain from the investment of working capital (R4): *Reserve of Working Capital →+ Investment of Working Capital →+ RoI on Working Capital →+ Reserve of Working Capital*
c. The potential growth/drag-down effect due to the adequacy/deficit in capacity for winning the potential new projects (R5): *Potential New Projects →+ Indicated Capacity →+ Budget Allocation for Acquiring Capacity →+ Capacity Acquisition →+ Capacity Balance →+ Availability of Capacity →+ Effort in Project Execution →+ Successful Execution of Projects →+ Market Reputation →+ Clientele →+ Potential New Projects*
d. The potential growth/drag-down effect due to the adequacy/deficit in capacity for ongoing projects (R6): *Ongoing Projects →+ Indicated Capacity →+ Budget Allocation for Acquiring Capacity →+ Capacity Acquisition →+ Capacity Balance →+ Availability of Capacity →+ Effort in Winning New Projects →+ New Projects →+ Ongoing Projects*
e. The turnover effect (R7): *Turnover →+ Reserve of Working Capital →+ Budget Allocation for Acquiring Capacity →+ Capacity Acquisition →+ Capacity Balance →+ Availability of Capacity →+ Effort in Project Execution →+ Successful Execution of Projects →+ Turnover*

more market reputation in turn. This core market growth loop is important to explain the performance of any construction business as it touches into the main source of revenue.

An exogenous variable, "Other Available Projects in the Market" has been linked to "Potential New Projects" (Figure 2) – this means that besides the clientele of the construction company, there would also be other available projects in the market. More projects would be available in the market if the economy is doing well and *vice versa*.

The second reinforcing FBL R2 explains another growth process, which is related to the general growth-oriented behaviour of the company owners as entrepreneurs. They work for turnover and profit from projects, and the more they get them, the more appetite (or desire) they develop and put more effort to get them more. The expectation of financial reward is one of the strongest growth motivators of business owners (Davidsson, 1989), and it is truer in construction business where the turnover and profit are critical for business operations. In fact, more profit is highly crucial for the firms to grow (Davidsson, Steffens and Fitsimmons, 2009), and this second reinforcing FBL explains how the success or failure of achieving the very bottom line could influence the effort and performance in construction business.

An exogenous variable "Entrepreneurial Drive" has also been added and linked to the "Appetite for New Projects" indicating that besides the appetite the owners develop because of turnover and profit, they would also be driven by their entrepreneurship – staunch entrepreneurs might keep on striving even in the situation of low turnover and less profit (Barringer, Jones and Neubaum, 2005; Kolvereid, 1992), and such entrepreneurial orientation supports the growth of a firm (Moreno, Casillas and Moreno-Mendez, 2008).

The second and third categories of FBLs (B1 to B2 and B3 to B4) represent the limiting process developed due to the growth processes explained by the two reinforcing loops, R1 and R2. In the process of company growth, efforts are needed in winning new projects and in the execution of ongoing projects. These efforts require capacities for realizing the intended outcome – the more the amount of efforts, the more the

capacities they will consume. In this research, the capacities are broadly divided into the financial and other capacities. In fact, capacities are backed-up by relevant resources, and as such, financial capacities primarily require financial resources and other capacities require their relevant resources. Other capacity resources in this research are defined as the whole set of resources required for operations of the company, and for the management and execution of projects. The resources are the human, material, equipment, land, building, all the facilities and service (provided by sub-contractors) resources that are consumed/deployed by the company.

The balancing loops from B1 to B2 show that the efforts consume the cash, and B3 to B4 show that they consume other capacity resources. As a result, the stocks of these resources get depleted and their availability would be reduced. The less the availability of these cash and other capacity resources, the less effective the efforts would tend to be, and thus the two growth loops (R1 and R2) would be affected. If the availability of resources continues to be low, then it might even turn the growth loops into declining loops, which could eventually pull down the business into a state of poor performance. Therefore, the limiting effects of the balancing loops from B1 to B4 could be detrimental to the system if they are not properly checked.

The fourth and fifth categories of FBLs (B5 to B8 and B9 to B12) explain how the construction company would manage its finance and other capacities to check or control the limiting effects of the balancing loops, B1 to B4. On the financial management side, maintaining sufficient operational cash balance, or in other words, cash flow management is one of the most challenging tasks in construction business. The cash balance could be managed by withdrawing cash from the reserve of the company's working capital (loop B5) or by borrowing from financial institutions (loop B6). Borrowing would increase the working capital, but it might take time to arrange the indicated amount to be borrowed, and it has to be paid back eventually with the interest amount. On the other hand, the main source of working capital would be the turnover in terms of successive payments gained in the process of project execution. The working capital could also be increased with the reinvestment of retained earnings (loop B7) from the turnover after deducting dividend payments to shareholders of the company (loop B8), and by investing the amount of working capital to get a return on its investment (loop R4). In some cases, equity investment could also be sought to increase the working capital reserve.

On the side of capacity management, the reserve of working capital would be used as a source to finance the capacity resources. There could be three different ways with which the capacity would be arranged and maintained. First, in order to acquire new capacity, the budget would be allocated as per the indicated (or desired) capacity for Potential New Projects and Ongoing Projects (loop B9). Second, to maintain the balance of the capacity in possession, the required expenditure (the overhead expenses) would also need to be arranged from the reserve of working capital (loop B10). Thirdly, the expenditure due to consumption/deployment of capacity for the Effort in Winning New Projects (loop B11) and the Effort in Project Execution (loop B12) would also need to be covered by the working capital.

The last or sixth category of FBLs (R3 to R7) represents the reinforcing loops or processes that get developed in the system. Loop R3 explains the process of potential debt trap, meaning that if the company relies more on borrowed money to secure finance, and if the interest rate is significant but return on debt investment is not promising, then the company's debt liabilities could get escalated. Loop R4, on the other hand, explains the situation whereby the company could enjoy the progressive return on investment if it invests the idle or apportioned amount of working capital in other portfolios rather than in the main business of new or ongoing projects. The requirement here is, the quantum of the apportioned working capital and rate of return should be significant to realize the progressive benefit. Loops R5 and R6 explain the potential growth/drag-down effect due to adequacy/deficit in the capacity for winning potential new projects and for ongoing projects respectively. Loop R7 explains the role of turnover in increasing the reserve of working capital and in the allocation of the budget for capacity acquisition. The practice of allocating a good proportion of profit/retained earnings for reinvestment could have a positive effect in

increasing the reserve of working capital and in the allocation of budget for capacity acquisition, and at the same time, it also matters how much of the turnover the company allocates for capacity acquisition.

Each of the FBLs, individually, in the six sets as elaborated above, can explain the forces that have the potential to affect the construction business system in different ways. The two main growth loops R1 and R2, *ceteris paribus*, portray the exponential growth (or decline) of construction company, and the finance and other capacities related balancing loops explain the influence on the potential growth (or even decline) of the business. In fact, the individual FBL-based approach can be taken as the usual factor-based approach in addressing the relevant issues. However, as the FBLs are structurally interlocked with non-linear relationships and time delays, an individual factor-based approach, even if it is well-intentioned one, might not be effective in the overall explanation of the observed level of business performance.

Development of a Simulation Model

The conceptual model (Figure 2) was translated into a simulation model to do experiments with a set of policies and practices that are generally used by construction companies. STELLA Architect was used as a software to develop the simulation model. A case of a typical construction company in the SME category was used to contextualize the model. All the FBLs in the conceptual model were carefully incorporated in the simulation model, and to make it more operational and realistic, other structural details along with relevant variables were also added in the model. Further, in order to gain confidence in the simulation model, the variables and their structural relationships were crafted carefully with their clear and fundamental understanding in the context of a construction company. The whole exercise of model development was extensively iterative. The experiments, modifications, and learning processes with the simulation model were continued with a range of extreme and intermediate possibilities in parameter values and structural relationships till a reasonable level of confidence was gained in the outcome of simulation runs.

THE CASE OF A CONSTRUCTION COMPANY

Before going into a detailed description of the simulation model, first, a case of a construction company is now presented. The main purpose of this case description is to provide a context for the generic conceptual framework.

- The case considered is of a general construction company with the size and scale of an SME, which is operating since the last 15 years in a relatively unstable and competitive market in a developing economy. The market is fairly sensitive to the performance of the company, which means information about the project performance of the company spreads steadily in the market, and the track record or market reputation affects the clientele and potential new projects from the market.
- The company is owned by a small group of partners.
- The perspective in the model is that of the company owners.
- The company is a genuine and growth-oriented construction company.
- Structural outline on the projects (Figure 3): The construction company would win new projects from the available potential projects which could be from the clientele of the company or the construction market. Once the new projects are won, they are internalized as the ongoing projects for execution, and if the execution is successful, then they would be the completed projects which would eventually be archived as a stock of the successful projects. However, if the execution is not successful, such projects would be abandoned as failed projects which would be archived as a stock of the failed projects.

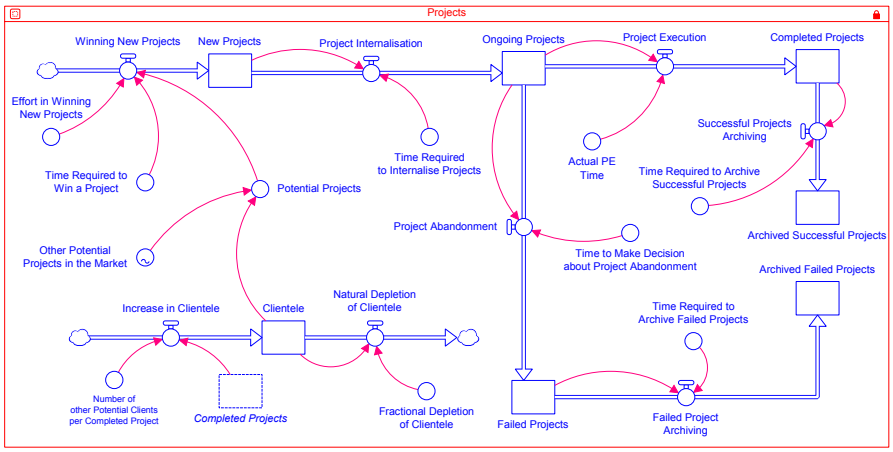

Figure 3. The Projects Sector

- Structural outline on the working capital and cash flow (Figure 4): Working capital is the capital used by the company for day-to-day operations. It is the balance of current assets and the current liabilities. The stock of cash is also a part of working capital in the form of the most liquid current assets. The inflow into the stock of working capital would be the collection of accounts receivables, equity investment, reinvestment of retained earnings, earned interest rate, and the borrowed capital amount. The outflow, on the other hand, would be the payments on the borrowed loan, replenishment of cash as per requirements, budgetary expenditure on the acquisitions of capacities for project operations, and project management and execution. The stock of cash would be maintained using the available working capital, and the cash would be disbursed for the account payables for projects, and the direct (projects) and indirect (company office) overhead amounts. Compensation for mobilization costs for new projects and the retention amount on payments for project execution would also affect the receivables and payables.

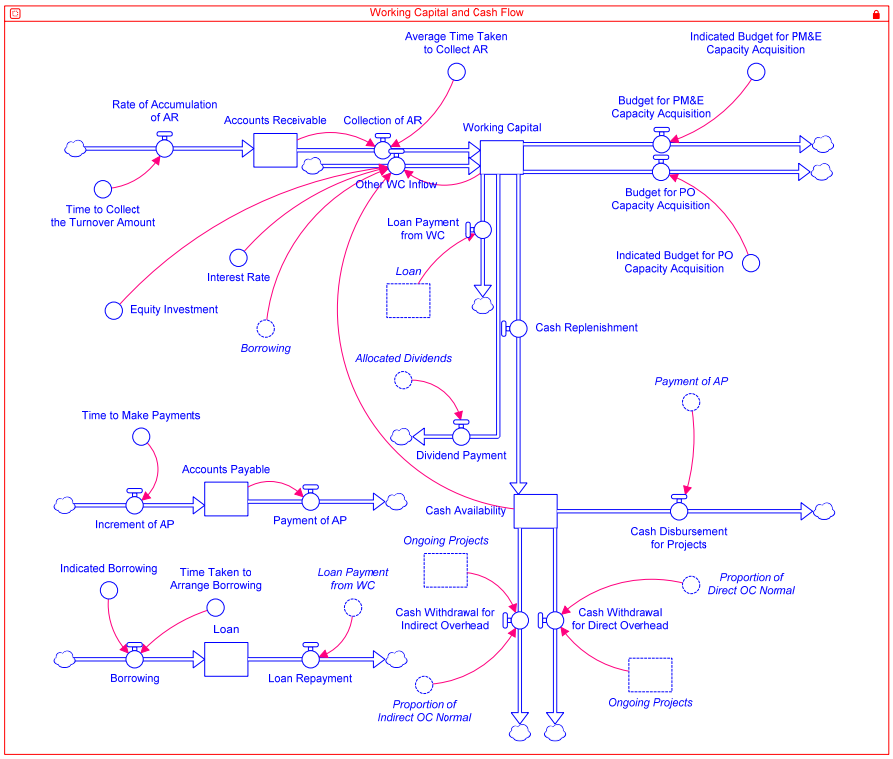

Figure 4. The Working Capital and Cash Flow Sector

- Structural outline on the capacities of the company (Figure 5): Construction business generally operates at two levels, one is at the head office and the other at project offices. Therefore, in order to operationalize in the simulation model, the concept of capacity has been divided into the Project Operations (PO) Capacity as the capacity at the head office and the Project Management and Execution (PM&E) Capacity as the capacity at the project offices. The PO capacity is generally needed and consumed for winning new projects and for providing operational support for ongoing projects, whereas the PM&E capacity is needed and consumed directly for the management and execution of ongoing projects. Both PO and PM&E capacities could be adjusted as per the requirements, but the acquisitions or adjustments of the capacities would be affected by the budget adequacy for acquisitions, time delay for adjustments, and the capacity deployment policy of the company. The capacity deployment policy mainly relates to the discretionary policy of the company on whether to fully or partly acquire and deploy the indicated (or required) capacities. On the other hand, the turnover and attrition would drain out the respective capacities.

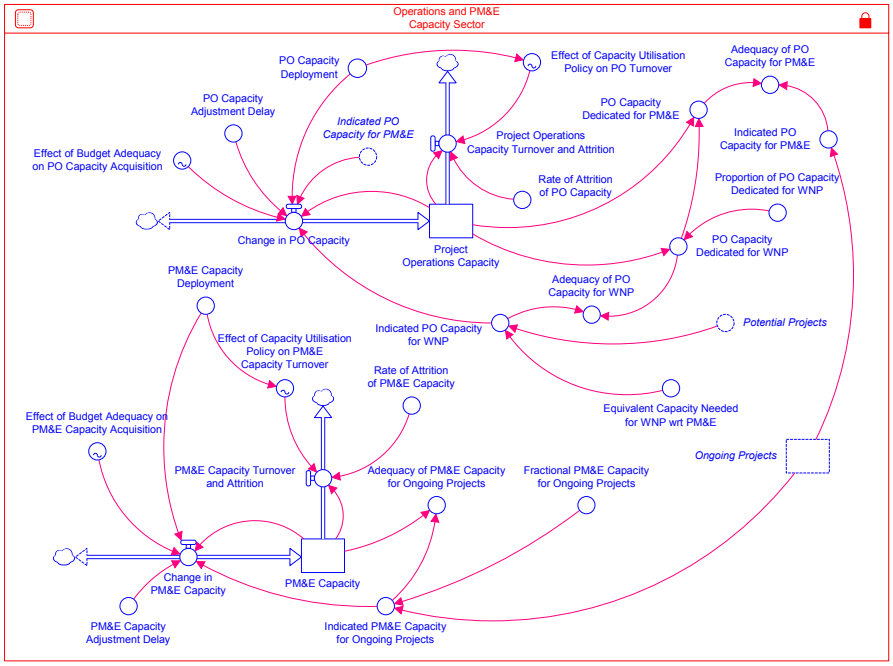

Figure 5. The Operations and PM&E Capacity Sector

- Structural outline on the costs and profit (Figure 6): Costs of running a project-based construction business can be divided into actual project costs, direct overhead costs (at project office), and indirect overhead costs (at the head office). The balance between these costs and the turnover amount would be the profit figure for the company. The expected costs and profit amounts would be realized if the projects are completed within the planned time duration. However, if there is alteration in the planned time duration of the projects, the costs and profit figures would be affected. Longer time duration means more actual costs and less actual profit. Accumulation of actual profit would be taken as the retained earnings, and it would be divided into dividends for shareholders and reinvestment portion for the company business. The proportion of the division depends on the profit allocation policy of the company. The profit achievement ratio is the ratio of the actual and expected profit, and the more the value of the ratio, more would be the sense of profit achievement. This particular sense of achievement in the bottom line of the business would affect the appetite for the growth of the business. The higher

profit achievement ratio develops more appetite for profit, and that is why the owners of the company would be looking for more new projects to get more business and profit.

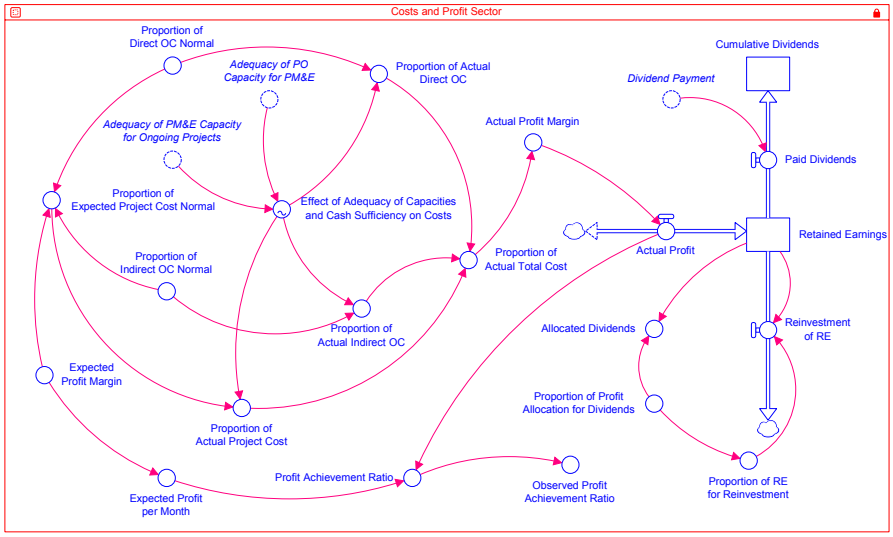

Figure 6. The Costs and Profit Sector

Other structural details on the entire model of the construction company are presented in terms of model equations in the Appendix. The full model could be obtained upon request to the first author of this paper.

PARAMETERS FOR THE BASE RUN

In order to further make the context of the construction company more specific, a set of parameters need to be specified and used for simulation experiments (see Table 2).

To start with, first, the type of projects the company normally prefers to win from the market are small to medium size projects with an average turnover value in between USD 24 and 30 million per project, and it needs to be completed in the average estimated or expected time duration of 24 months. The interest rate on loan would be 14% per annum and the return on investment, 9% per annum. The proportion of debt financing the company secures to cater to cash deficiency would be 100%, meaning that banks are available and supportive to the business, but it takes 3 months in average as a procedural delay to bring-in the required loan amount to the company account. The payback period is generally 10 years. The current PO and PM&E capacities of the company are equivalent to 5 projects – the company has currently a capacity of operations, management, and execution of 5 normal projects at a time. In general, in order to win a new project, it would take one third (33%) of the full operations support capacity required for one PM&E. In addition, to bear the costs of deployment (for projects) and maintenance (in terms of direct and indirect overhead costs) of the capacities, the company also allocates budget for new capacity acquisitions. For the PO and PM&E capacity acquisitions, 5% and 10% of the turnover respectively would be allocated as the budget for new capacity acquisitions.

On the side of payments on project execution, the company would receive compensation for mobilization upfront, and it would be 10% of the contract amount which needs to be paid back with deductions on subsequent running bills. A similar arrangement is also there for sub-contractors of the company, and the upfront compensation for all the sub-contractors would be 2% of the project cost. The retention of payments on completed works for the company and subcontractors would be 25% of the running bill amount, which would eventually be paid back after the completion of works. It would take one month to settle the ongoing accounts payables and accounts receivables.

Table 2. Key Parameters for the Base Run

Average turnover value per project: Random in between USD 24 million and 30 million
Average time duration of projects: 24 months
Interest rate on loan: 14% per annum
Return on investment: 9% per annum
Proportion of debt financing to cater to cash deficiency: 100%
Average time taken to borrow the required loan: 3 months
Current project operations (PO) capacity: 5 projects
Current project management and execution (PM&E) capacity: 5 projects
Equivalent PO capacity needed for winning new projects with respect to that for one PM&E: 0.33
Fractional turnover allocated for PO capacity acquisition: 0.05
Fractional turnover allocated for PM&E capacity acquisition: 0.10
Compensation for mobilisation for the company: 10% of the contract amount
Compensation for mobilisation for subcontractors: 2% of the project cost
Retention amount on the continuous payments on completed works for the company and subcontractors: 25%
Time duration for paying the accounts payable: 1 month
Time duration for receiving the accounts receivable: 1 month

Besides the parameters listed in Table 2, the average time delay in different processes and operations would also be important to understand the dynamics of the construction business. In order to win new projects, the company would need to put in effort for about 6 months on average, which means the time delay in winning a new project would be 6 months on average. Once the contract has been signed, it would take a month to internalize the project. The estimated normal execution time of a project would be 24 months, but the actual time taken for project execution depends on the performance of the company and project-level operations. Once the project has been successfully completed, within a month it would be recorded as an archived successful project. However, if the project takes more than 2 to 3 times the estimated time duration, a part or even the whole of the project would be abandoned as a failed project. It would take 24 months to declare the set of delayed projects as failed projects, and then after they would be recorded as archived failed projects in a month. It is also important to consider the time taken to arrange for or to adjust the PO and PM&E capacities as per their demand situation. On average, it would take 3 months to adjust the PO capacity, and 2 months for the PM&E capacity. These time-delay figures indicate the efficiency of the company in arranging the respective capacities as per their demand situation.

Discussion on the Output of Simulation Experiments

The key parameters explained in the previous section represent a context of a typical construction company, and within the context, it is attempted to develop an understanding of the implications of some selected policies and practices that construction companies use in their business.

Construction companies cannot survive without ongoing projects, and thus their focus and tendency would be to win more and more new projects. It has been widely observed that the obsession of volume and the perception of "more project revenue means more profit" represent the dominant mind-set of contractors (Rice 2016, 2013). With such a mind-set, they tend to be aggressive in winning projects even with low-profit margins, especially when the market is competitive (Hedley, 2011).

On the side of capacity management, stretching the available capacity at both the head office and project site offices is a general practice used by construction companies. Probably because of the uncertainty in getting projects, they are generally reluctant to add to their current capacity and to build any extra capacity cushions (Gill, 2015). They discharge the capacity once the project is over, and they rarely work with the reserve of their own pool of capacity to be proactive in the business.

These practices of construction companies indeed seem to be rational from a contractor's perspective. Projects are essential food for survival for the business, and it is highly challenging to win them. Therefore, contractors tend to be obsessed with the accumulation of project volume and they put good effort in winning new projects. Projects bring-in revenue and cash, and they need to be won even with low-profit margins in difficult situations. As there is so much uncertainty in getting new projects, the current capacity should be fully exploited and there is no point in arranging for unnecessary and extra capacity cushion.

In the simulation experiments, these practices were incorporated with the quantified values of relevant parameters. First, the effort for winning more new projects (WNP) needs the capacities and resources which have to be drawn from the capacities at project operations (PO) level. More emphasis on winning new projects means more proportion of PO capacity to be allocated for marketing, bidding for contracts, negotiation, client relationship maintenance, and so on. This also means that the PO capacity needed for ongoing project management and execution (PM&E) would be compromised. The PO capacities for WNP and PM&E are mutually exclusive, and it is more so in resource-constrained SMEs.

Second, the profit margin of projects with which construction companies would work depends on the relative scale of the project and the risk appetite of the company. The accepted profit margin is the balance when the expected overhead amounts and cost expenses are deducted from the estimated turnover of the project.

Third, the sense of adequacy of deployed capacities with respect to the indicated ones reflects the deployment policies of the PO capacity at the head office and the PM&E capacity at site offices. The company could deploy stretched, just adequate, or even extra buffer capacities.

Fourth, the time delay in arranging the indicated capacities is another parameter that reflects the company's ability or preference in the timely management of the desired capacity. If there is no proactive arrangement of capacities, it will surely take at least the required time to arrange for newly indicated capacities.

These four parameters have been used to represent the policies and practices of the construction companies as mentioned before, and Figure 7 presents a set of relevant simulation runs that reflect the consequences of the policies and practices.

In Figure 7, a total of five simulation runs (SRs) have been presented on the patterns of six selected variables over a period of 144 months (12 years). These 6 variables represent some of the key performance indicators of the construction business. These five sets of SRs actually demonstrate the implications of more and more emphasis on new projects, accepting projects with lower profit margins, and tighter capacity deployment. The PO capacity allocation for winning new projects (WNP) is increased from 30% to 40%, 50%, 60% to 70% in SRs from 1 to 5 successively. Likewise, the profit margin is decreased from 30% to 25%, 20%, 15% to 10%. The proportion of PO and PM&E capacity deployment is decreased from 90% to 85%, 80%, 75% to 70% of the indicated capacity successively. The PO and PM&E capacity adjustment delays, however, have been fixed 3 months and 2 months respectively for this set of simulation runs.

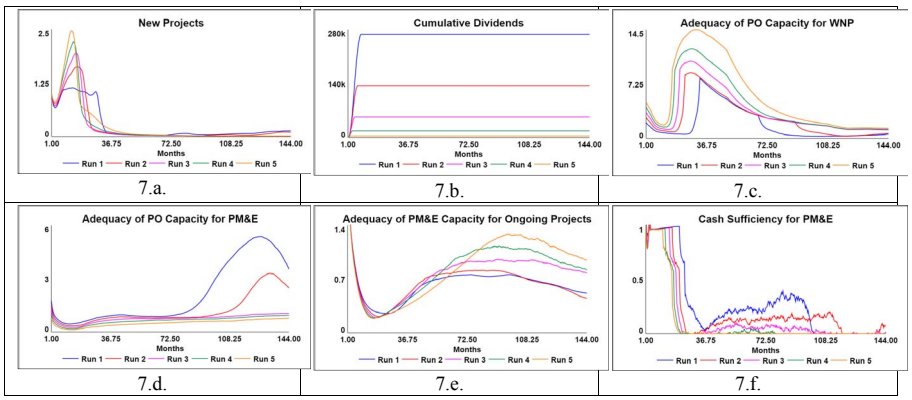

Figure 7. Implications of the Emphasis on Winning More New Projects, Lower Profit Margins, and Tighter Capacity Deployment

The simulation outputs (from Figures 7.a. to 7.f.) demonstrate that more emphasis on new projects, lower (or competitive) profit margins and tighter capacity deployment eventually deteriorates the performance of construction business to the situation of absolute failure. The main purpose of dedicating more PO capacity for winning new projects is to add a volume of projects, and it could bring in new projects for some time (Figure 7.a.). However, it would be difficult to sustain the increase in new projects because in SMEs, the limited PO capacity has to be compromised and the effective head office attention on ongoing projects would get reduced. As a result, the effort in PM&E at the site would be affected. Besides that, new projects mean more demand of the capacities, and worse, if the capacities are stretched then the adequacies (Figure 7.d. and 7.e.) would be lesser to meet the indicated capacities. Another interesting observation is that the adequacy of PO capacity for WNP turned out to be far more than that is indicated (or required) (Figure 7.c.) because the actually needed PO capacity for WNP would be generally less than the perceived need. Therefore, allocating more and more PO capacities for winning new projects is a faulty practice as it reduces the effective PO capacities for PM&E at the project sites.

Another observation is that the cash sufficiency gets worse successively in the five SRs (Figure 7.f.) despite the fact that cash deficiency would be covered 100% by borrowing. The main reasons are: there is some procedural delay in borrowing the indicated cash amount, and the number of new projects if get delayed in the process of execution due to lower capacity adequacy, they would not fetch-in the receivables.

Overall, the set of consequent business performance demonstrates the failure patterns of growth and decline. The effort to win new projects brings in more projects, more turnover, more budget availability for capacities, more added capacities, and more effort to win new projects in turn. However, due to the tighter capacity deployment practices in the situation of its increasing demand create subsequent capacity deficiencies, and it starts repeatedly affecting the effective effort. This turns the virtuous structure of the main reinforcement loops (R1 and R2 in Figure 2) into vicious, and thus the business would plunge to failure.

Figure 8 presents another set of simulation runs. This set presents the experimental output of the inquiry to learn whether the emphasis on WNP is always counterproductive. Three groups of results have been produced for the purpose. In the first group (Figure 8.a. to 8.f.), PO capacity allocated for WNP has been successively increased from 10% to 15%, 20%, 25% to 30% in the five runs at the profit margin of 20%. In the second group (Figure 8.g. to 8.l.), PO capacity dedicated for WNP has been again successively increased from 10% to 15%, 20%, 25% to 30% in the five runs at the profit margin of 30%. Likewise, in the third group (Figure 8.m. to 8.r.), PO capacity allocated for WNP has been successively increased from 10% to 15%, 20%, 25% to 35% in the five runs at the profit margin of 40%. In all the three groups, the proportions

of PO and PM&E capacity deployment have been fixed at 80%, and the capacity adjustment delays are locked at 3 and 2 months respectively. In short, the three groups of simulation output demonstrate how the company performance would be affected when winning new projects are successively more emphasized in three increasing levels of profit margin with relatively higher proportions of PO and PM&E capacity deployment and longer capacity adjustment delay.

The results of this experiment show that a higher level of profit margin would help to bring in more projects if more emphasis is given (or more PO capacity is deployed) for WNP. In the first group of SRs, at the lower 20% of profit margin, 10% of PO capacity deployed for WNP could ensure sustained growth of new projects for the company. In the second group of SRs, at the next higher 30% of profit margin, 10% and 15% of PO capacity deployed for WNP could ensure the growth of new projects. In the third group of SRs, at further higher profit margin of 40%, 10%, 15%, 20% and 25% of PO capacity deployed for WNP could ensure sustained growth of new projects for the company. However, in all the three groups, it is found that the extent of PO capacity deployed for WNP have a certain limit to yield more new projects

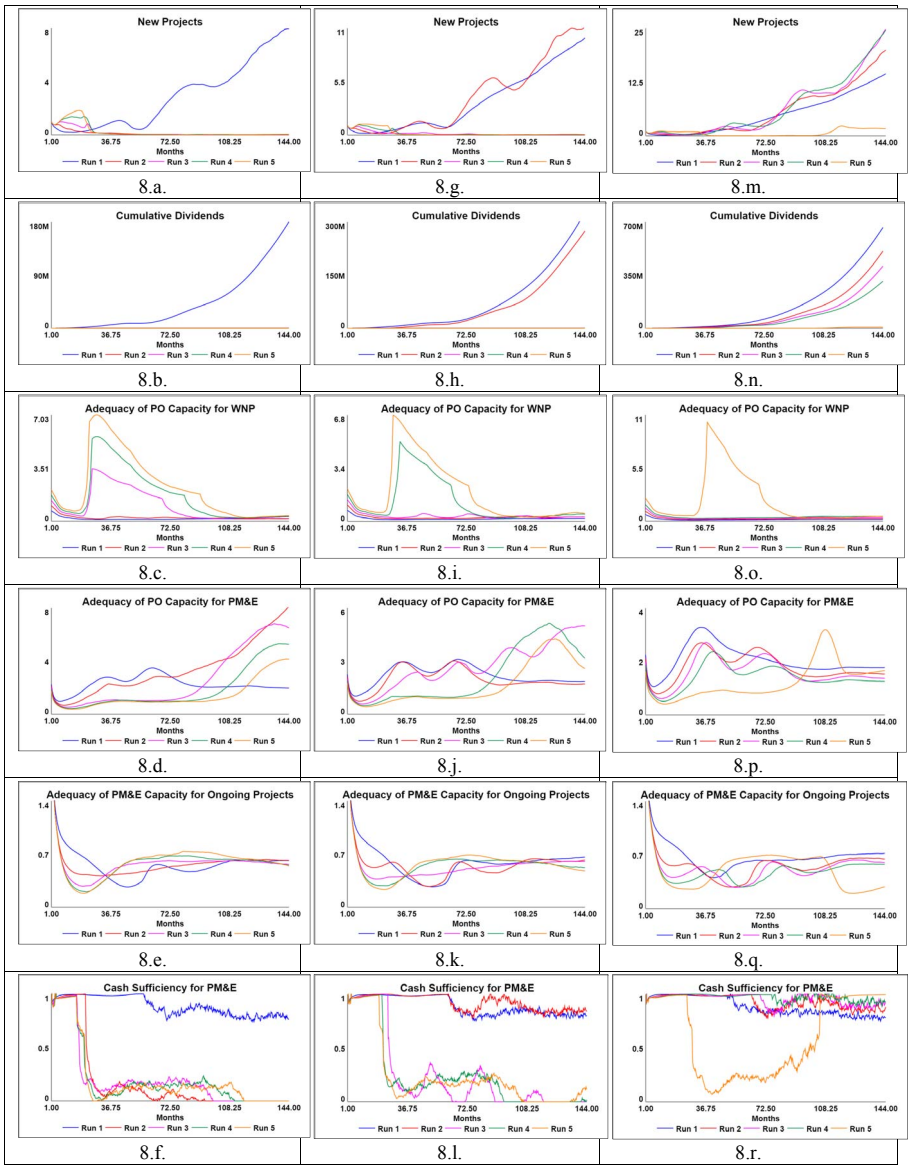

Figure 8. Implications of Different Profit Margins and Emphasis on Winning More New Projects

– in the first group not more than 10%, in the second 20%, and in the third group, not more than 25% PO capacity deployed for WNP could ensure growth of new projects. This means more emphasis on winning new projects could be a good policy option for sustained and higher business growth, provided that it is supported by adequate profit margin, but again there is a limit on the effectiveness of emphasis on winning new projects in bringing-in real new projects. Another observation is, within the limit, more profit margin would help bring in a larger scale of business in terms of the number of projects, revenues, and resulting dividend amounts. More profit margin means more reinvestment, more resulting capacities, and more cash sufficiency. It also means more sense of achievement and more appetite for new projects. However, the limit would be crossed when the PO capacity gets excessively deployed for WNP (Figures 8c, i and o).

Another set of experimental results is presented in Figure 9. The purpose of this experiment is to explore whether more profit margin would always ensure sustained growth of the business. In Figure 9, for the first group (Figure 9.a. to 9.f.) of simulation, the profit margin is fixed at 40%, for the second group (Figure

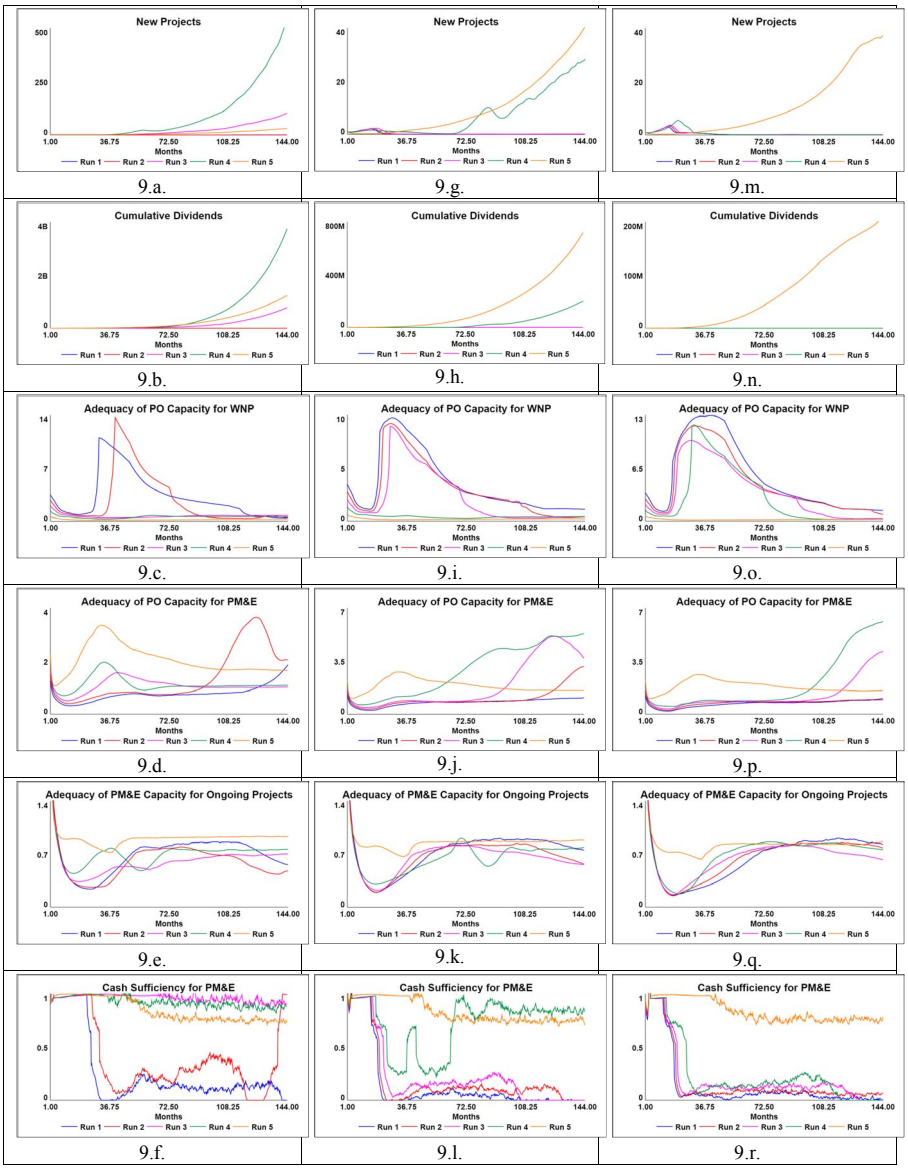

Figure 9. Implications of Capacities Management vis-à-vis Different Profit Margins

9.g. to 9.l.), it is fixed at 20%, and for the third group (Figure 9.m. to 9.r.), 5%. The profit margins are successively decreased in the groups presented in three columns.

For each of the three groups, the PO capacity allocated for WNP is decreased from 50% to 40%, 30%, 20% to 10% in SRs 1 to 5 respectively. The proportion of PO and PM&E capacity deployment is increased from 70% to 75%, 80%, 85% to 90% of the indicated capacity respectively. The PO capacity adjustment delay is decreased from 3 months to 2.5, 2, 1.5 to 1 months, and the PM&E capacity adjustment delay is decreased from 2 months to 1.5, 1, 0.75 to 0.5 months. Overall, the whole set of effective capacities are successively increased in the five SRs in each of the three groups.

The experimental results clearly indicate that more profits do help to develop business in larger scales in terms of many projects, revenues, and resulting dividend amounts. However, it is also evident that even a very attractive profit margin of 40% would not be sufficient to sustain the business if it takes longer time to adjust the current capacities as per indicated ones, capacity deployments are tighter, and excessively more PO capacity is allocated for WNP. More profits do support the business with the relatively less effective capacities, but again, higher profit margins do have limits. On the other hand, a lower profit margin of 20% or even a meagre 5% would help sustain and grow the business if the effective capacities are adequate. The key point is, the deployment and adequacy of capacities should be ensured vis-à-vis the level of profit margin for the business to successfully scale up.

Conclusions

This research investigated why construction companies would generally fail, and how they could sustain and grow their business. A range of performance modes of a typical construction company has been explored by simulating the underlying causal structure. It was found that the policies and practices that emphasize winning more and more new projects generally create the situation of biting more than what the company could chew. Worse it would be, when companies prefer to be more competitive by accepting new projects with lower profit margins, and they work with tighter capacity deployment policies.

On the other hand, it was also found that emphasis on winning new projects would help to grow the business, provided that it is supported by adequate profit margins. However, certain profit margins, even the higher ones, do have a limit in letting the company allocate its capacity and resources in winning more and more new projects. It was also observed that more emphasis on winning new projects, if properly synchronized with higher profit margins, could lead to a larger scale growth of the business in terms of the number of projects, revenues, and resulting dividend amounts.

Further, higher profit margins, even though they look attractive, would not necessarily help sustain the business if it takes a longer time to adjust the current capacities as per the indicated ones, capacity deployments are tighter, and excessively more capacity and resources are allocated for winning new projects.

This research considered and experimented with a set of selected managerial policies and practices that can lead the construction business to failure, sustenance, or growth. Overall, in order to achieve expected growth or sustenance, it is found that a certain level of balance needs to be secured on how much emphasis is to be given to win new projects, how much profit margins to work with, and how much capacities to be arranged and deployed for project operations, management, and execution.

The business performance modes observed in this research were the experimental outcomes within the context of a typical construction company that is explained by the baseline situation and parameters. It is a conceptual or more a semi-empirical work. The advantage of such study is that a range of possible parameter values and information structure in the model could be used to create different sets of contexts and policies for experimental learning. However, the use of experimental data, although they are realistic, might be questionable from the pure empiricist perspective which emphasizes the importance of real life data.

Therefore, for further research, it is recommended to use the pure empirical data in the simulation model to gain more realistic and practical insights. For such research, all the required longitudinal data need to be collected preferably by conducting thorough case or ethnographic studies in the consenting construction firms.

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Appendix

MODEL EQUATIONS

Top-Level Model:

Accounts_Payable(t) = Accounts_Payable(t - dt) + (Increment_in_AP - Payment_of_AP) * dt {NON-NEGATIVE}

INIT Accounts_Payable = 1500000; INFLOWS: Increment_in_AP = (Net_Payments_to_be_Made/Time_to_Make_Payments)-Total_Retention_Amount_per_Month_from_Subs+Total_Retention_Amount_to_be_Paid_per_Completed_Project_per_Month_to_Subs+CfM_for_Subs-Monthly_Deductible_Amount_of_CfM_for_Subs {UNIFLOW}; OUTFLOWS: Payment_of_AP = Accounts_Payable {UNIFLOW}

Accounts_Receivable(t) = Accounts_Receivable(t - dt) + (Rate_of_Accumulation_of_AR - Collection_of_AR) * dt {NON-NEGATIVE}

INIT Accounts_Receivable = 1000000; INFLOWS: Rate_of_Accumulation_of_AR = (Net_Turnover_per_Project_per_Month/Time_to_Collect_the_Turnover_Amount)+Received_CfM_Amount {UNIFLOW}

OUTFLOWS: Collection_of_AR = Accounts_Receivable/Average_Time_Taken_to_Collect_AR {UNIFLOW}

Archived_Failed_Projects(t) = Archived_Failed_Projects(t - dt) + (Failed_Project_Archiving) * dt {NON-NEGATIVE}

INIT Archived_Failed_Projects = 2; INFLOWS: Failed_Project_Archiving = Failed_Projects/Time_Required_to_Archive_Failed_Projects {UNIFLOW}

Archived_Successful_Projects(t) = Archived_Successful_Projects(t - dt) + (Successful_Projects_Archiving) * dt {NON-NEGATIVE}

INIT Archived_Successful_Projects = 10; INFLOWS: Successful_Projects_Archiving = Completed_Projects/Time_Required_to_Archive_Successful_Projects {UNIFLOW}

Cash_Availability(t) = Cash_Availability(t - dt) + (Cash_Replenishment - Cash_Disbursement_for_Projects - Cash_Withdrawal_for_Indirect_Overhead - Cash_Withdrawal_for_Direct_Overhead) * dt {NON-NEGATIVE}

INIT Cash_Availability = 500000; INFLOWS: Cash_Replenishment = Required_Cash_per_Month_for_PE+Indicated_Withdrawal_from_Equity {UNIFLOW}; OUTFLOWS: Cash_Disbursement_for_Projects = Payment_of_AP {UNIFLOW}; Cash_Withdrawal_for_Indirect_Overhead = Ongoing_Projects*Estimated_Average_Turnover_per_Project_per_Month*Proportion_of_Indirect_OC_Normal {UNIFLOW}

Cash_Withdrawal_for_Direct_Overhead = Ongoing_Projects*Estimated_Average_Turnover_per_Project_per_Month*Proportion_of_Direct_OC_Normal {UNIFLOW}

Clientele(t) = Clientele(t - dt) + (Increase_in_Clientele - Natural_Depletion_of_Clientele) * dt {NON-NEGATIVE}

INIT Clientele = 20; INFLOWS: Increase_in_Clientele = Completed_Projects*Number_of_other_Potential_Clients_per_Completed_Project {UNIFLOW}; OUTFLOWS: Natural_Depletion_of_Clientele = Clientele*Fractional_Depletion_of_Clientele {UNIFLOW}

Completed_Projects(t) = Completed_Projects(t - dt) + (Project_Execution - Successful_Projects_Archiving) * dt {NON-NEGATIVE}

INIT Completed_Projects = 2; INFLOWS: Project_Execution = (Ongoing_Projects+(Ongoing_Projects*Addition_of_Project_Scope))/Actual_PE_Time {UNIFLOW}; OUTFLOWS: Successful_Projects_Archiving = Completed_Projects/Time_Required_to_Archive_Successful_Projects {UNIFLOW}

Cumulative_Dividends(t) = Cumulative_Dividends(t - dt) + (Paid_Dividends) * dt {NON-NEGATIVE}

INIT Cumulative_Dividends = 0; INFLOWS: Paid_Dividends = Dividend_Payment {UNIFLOW}; Failed_Projects(t) = Failed_Projects(t - dt) + (Project_Abandonment - Failed_Project_Archiving) * dt {NON-NEGATIVE}

INIT Failed_Projects = 2; INFLOWS: Project_Abandonment = Ongoing_Projects*Effect_of_Actual_Completion_Time_on_Project_Failure/Time_to_Make_Decision_about_Project_Abandonment {UNIFLOW}; OUTFLOWS: Failed_Project_Archiving = Failed_Projects/Time_Required_to_Archive_Failed_Projects {UNIFLOW}

Loan(t) = Loan(t - dt) + (Borrowing - Loan_Repayment) * dt {NON-NEGATIVE}

INIT Loan = 1000000; INFLOWS: Borrowing = (IF Creditworthiness>=1 THEN (Indicated_Borrowing/Time_Taken_to_Arrange_Borrowing) ELSE (0)) {UNIFLOW}; OUTFLOWS: Loan_Repayment = Loan_Payment_from_WC {UNIFLOW}

New_Projects(t) = New_Projects(t - dt) + (Winning_New_Projects - Project_Internalisation) * dt {NON-NEGATIVE}

INIT New_Projects = 1; INFLOWS: Winning_New_Projects = Potential_Projects*Effort_in_Winning_New_Projects/Time_Required_to_Win_a_Project {UNIFLOW}; OUTFLOWS: Project_Internalisation = New_Projects/Time_Required_to_Internalise_Projects {UNIFLOW}

Ongoing_Projects(t) = Ongoing_Projects(t - dt) + (Project_Internalisation - Project_Execution - Project_Abandonment) * dt {NON-NEGATIVE}

INIT Ongoing_Projects = 2; INFLOWS: Project_Internalisation = New_Projects/Time_Required_to_Internalise_Projects {UNIFLOW}

OUTFLOWS: Project_Execution = (Ongoing_Projects+(Ongoing_Projects*Addition_of_Project_Scope))/Actual_PE_Time {UNIFLOW}

Project_Abandonment = Ongoing_Projects*Effect_of_Actual_Completion_Time_on_Project_Failure/Time_to_Make_Decision_about_Project_Abandonment {UNIFLOW}

PM&E_Capacity(t) = PM&E_Capacity(t - dt) + (Change_in_PM&E_Capacity - PM&E_Capacity_Turnover_and_Attrition) * dt {NON-NEGATIVE}

INIT PM&E_Capacity = 5; INFLOWS: Change_in_PM&E_Capacity = (Indicated_PM&E_Capacity_for_Ongoing_Projects-PM&E_Capacity)*PM&E_Capacity_Deployment*Effect_of_Budget_Adequacy_on_PM&E_Capacity_Acquisition/PM&E_Capacity_Adjustment_Delay; OUTFLOWS: PM&E_Capacity_Turnover_and_Attrition = PM&E_Capacity*(Effect_of_Capacity_Utilisation_Policy_on_PM&E_Capacity_Turnover+Rate_of_Attrition_of_PM&E_Capacity) {UNIFLOW}

Project_Operations_Capacity(t) = Project_Operations_Capacity(t - dt) + (Change_in_PO_Capacity - Project_Operations_Capacity_Turnover_and_Attrition) * dt {NON-NEGATIVE}

INIT Project_Operations_Capacity = 5; INFLOWS: Change_in_PO_Capacity = ((Indicated_PO_Capacity_for_WNP+Indicated_PO_Capacity_for_PM&E)-Project_Operations_Capacity)*PO_Capacity_Deployment*Effect_of_Budget_Adequacy_on_PO_Capacity_Acquisition/PO_Capacity_Adjustment_Delay; OUTFLOWS: Project_Operations_Capacity_Turnover_and_Attrition = Project_Operations_Capacity*Effect_of_Capacity_Utilisation_Policy_on_PO_Turnover*Rate_of_Attrition_of_PO_Capacity {UNIFLOW}

Retained_Earnings(t) = Retained_Earnings(t - dt) + (Actual_Profit - Paid_Dividends - Reinvestment_of_RE) * dt {NON-NEGATIVE}

INIT Retained_Earnings = 0; INFLOWS: Actual_Profit = Actual_Profit_Margin*Total_Turnover_per_Month; OUTFLOWS: Paid_Dividends = Dividend_Payment {UNIFLOW}

Reinvestment_of_RE = Proportion_of_RE_for_Reinvestment*Retained_Earnings/12 {UNIFLOW}

Time_Count(t) = Time_Count(t - dt) + (Rate_of_Time_Count) * dt {NON-NEGATIVE}

INIT Time_Count = 0; INFLOWS: Rate_of_Time_Count = 1 {UNIFLOW}

Working_Capital(t) = Working_Capital(t - dt) + (Collection_of_AR + Other_WC_Inflow - Budget_for_PM&E_Capacity_Acquisition - Budget_for_PO_Capacity_Acquisition - Loan_Payment_from_WC - Cash_Replenishment - Dividend_Payment) * dt {NON-NEGATIVE}

INIT Working_Capital = 1000000; INFLOWS: Collection_of_AR = Accounts_Receivable/Average_Time_Taken_to_Collect_AR {UNIFLOW}

Other_WC_Inflow = Equity_Investment+Borrowing+((Working_Capital+Cash_Availability)*Interest_Rate) {UNIFLOW}; OUTFLOWS: Budget_for_PM&E_Capacity_Acquisition = DELAY(Indicated_Budget_for_PM&E_Capacity_Acquisition, 3) {UNIFLOW}

Budget_for_PO_Capacity_Acquisition = DELAY(Indicated_Budget_for_PO_Capacity_Acquisition,3) {UNIFLOW}

Loan_Payment_from_WC = Loan*(.10/12)/(1-(1+.10/12)^(-12*10)) {UNIFLOW}

Cash_Replenishment = Required_Cash_per_Month_for_PE+Indicated_Withdrawal_from_Equity {UNIFLOW}

Dividend_Payment = Allocated_Dividends {UNIFLOW}

Actual_Completion_Time_wrt_Normal = SMTH1(Actual_PE_Time, 3)/Normal_Project_Completion_Time

Actual_PE_Time = (Normal_Project_Completion_Time*Effect_of_Cash_Sufficiency_on_PM&E*Effect_of_PM&E_Capacity_Adequay_on_PM&E*Effect_of_PO_Capacity_Adequacy_on_PM&E); Actual_Profit_Margin = 1-Proportion_of_Actual_Total_Cost; Addition_of_Project_Scope = 0

Adequacy_of_PM&E_Capacity_for_Ongoing_Projects = (PM&E_Capacity/Indicated_PM&E_Capacity_for_Ongoing_Projects)

Adequacy_of_PO_Capacity_for_PM&E = PO_Capacity_Dedicated_for_PM&E/Indicated_PO_Capacity_for_PM&E

Adequacy_of_PO_Capacity_for_WNP = PO_Capacity_Dedicated_for_WNP/Indicated_PO_Capacity_for_WNP

Adverse_Impression_in_Market = SMTH1((Failed_Projects/Completed_Projects), 24); Allocated_Dividends = Retained_Earnings*Proportion_of_Profit_Allocation_for_Dividends/12; Average_Time_of_Engagement_for_Subs = 8

Average_Time_Taken_to_Collect_AR = 1; Average_Time_to_Make_Payments_to_Subs_and_Suppliers = 1

Base_Appetite_for_New_Projects = GRAPH(Observed_Profit_Achievement_Ratio) (0.00, 0.03), (0.20, 0.09), (0.40, 0.17), (0.60, 0.31), (0.80, 0.57), (1.00, 0.99), (1.200, 1.35), (1.40, 1.59), (1.60, 1.77), (1.80, 1.92), (2.00, 2.00) Budget_Adequacy_for_PO_Capacity_Improvement = (Budget_for_PO_Capacity_Acquisition+Cash_Withdrawal_for_Indirect_Overhead)/Cost_of_PO_Capacity Budget_Adquacy_for_PM&E_Capacity_Acquisition = (Budget_for_PM&E_Capacity_Acquisition+Cash_Withdrawal_for_Direct_Overhead)/Cost_of_PM&E_Capacity

Cash_Deficiency = (IF Cash_Sufficiency_Period>1 THEN 0 ELSE (1-Cash_Sufficiency_Period)*Required_Cash_per_Month_for_PE)

Cash_Sufficiency_for_Direct_Overhead = Cash_Withdrawal_for_Direct_Overhead/Indicated_Cash_Requirmeent_for_Direct_Overhead

Cash_Sufficiency_for_Indirect_Overhead =Cash_Withdrawal_for_Indirect_Overhead/Indicated_Cash_Requirement_for_Indirect_Overhead

Cash_Sufficiency_for_PM&E = (Cash_Disbursement_for_Projects+Cash_Withdrawal_for_Direct_Overhead+Cash_Withdrawal_for_Indirect_Overhead)/Required_Cash_per_Month_for_PE; Cash_Sufficiency_Period = Cash_Availability/Required_Cash_per_Month_for_PE; CfM_for_Subs = Fractional_CfM_for_Subs*Total_Average_Cost_of_Ongoing_Projects_per_Month Compensation_for_Mobilisation_Costs_per_New_Project = Fractional_CfM_for_the_Company*Expected_Average_Turnover_per_Project

Cost_of_PM&E_Capacity = Fractional_Cost_for_PM&E_Capacity_Acquisition*Estimated_Average_Turnover_per_Project_per_Month*Ongoing_Projects

Cost_of_PO_Capacity = (Indicated_PO_Capacity_for_WNP+Indicated_PO_Capacity_for_PM&E)*Estimated_Average_Turnover_per_Project_per_Month*Fractional_Cost_for_PO_Capacity_Aquisition; Creditworthiness = ((Accounts_Receivable+Cash_Availability+Working_Capital)*5/(Accounts_Payable+Loan)); Current_Ratio = SMTH1(((Working_Capital+Accounts_Receivable+Cash_Availability+0.3*(Cost_of_PO_Capacity+Cost_of_PM&E_Capacity))/(Loan+Accounts_Payable)), 12); Effect_of_Actual_Completion_Time_on_Project_Failure = GRAPH(Actual_Completion_Time_wrt_Normal) (1.00, 0.00), (1.20, 0.00), (1.40, 0.00), (1.60, 0.00), (1.80, 0.00), (2.00, 0.00), (2.20, 0.05), (2.40, 0.15), (2.60, 0.29), (2.80, 0.53), (3.00, 1.00); Effect_of_Adequacy_of_Capacities_and_Cash_Sufficiency_on_Costs = GRAPH(Adequacy_of_PM&E_Capacity_for_Ongoing_Projects*Adequacy_of_PO_Capacity_for_PM&E*Cash_Sufficiency_for_PM&E)

(0.00, 2.00), (0.20, 1.87), (0.40, 1.71), (0.60, 1.50), (0.80, 1.25), (1.00, 1.00), (1.20, 0.89), (1.40, 0.83), (1.60, 0.81), (1.80, 0.80), (2.00, 0.80); Effect_of_Adequacy_of_PO_Capacity_for_Effort_in_WNP = GRAPH(Adequacy_of_PO_Capacity_for_WNP) (0.00, 0.01), (0.10, 0.03), (0.20, 0.07), (0.30, 0.14), (0.40, 0.29), (0.50, 0.49), (0.60, 0.72), (0.70, 0.86), (0.80, 0.94), (0.90, 0.98), (1.00, 1.00) Effect_of_Budget_Adequacy_on_PM&E_Capacity_Acquisition = GRAPH(Budget_Adquacy_for_PM&E_Capacity_Acquisition) (0.00, 0.00), (0.10, 0.05), (0.20, 0.12), (0.30, 0.21), (0.40, 0.32), (0.50, 0.50), (0.60, 0.66), (0.70, 0.80), (0.80, 0.90), (0.90, 0.97), (1.00, 1.00); Effect_of_Budget_Adequacy_on_PO_Capacity_Acquisition = GRAPH(Budget_Adequacy_for_PO_Capacity_Improvement) (0.00, 0.00), (0.10, 0.04), (0.20, 0.10), (0.30, 0.21), (0.40, 0.34), (0.50, 0.50), (0.60, 0.66), (0.70, 0.81), (0.80, 0.90), (0.90, 0.96), (1.00, 1.00) Effect_of_Capacity_Utilisation_Policy_on_PM&E_Capacity_Turnover = GRAPH(PM&E_Capacity_Deployment) (0.00, 1.00), (0.10, 0.46), (0.20, 0.23), (0.30, 0.10), (0.40, 0.04), (0.50, 0.03), (0.60, 0.01), (0.70, 0.01), (0.80, 0.01), (0.90, 0.01), (1.00, 0.00); Effect_of_Capacity_Utilisation_Policy_on_PO_Turnover = GRAPH(PO_Capacity_Deployment) (0.00, 1.00), (0.10, 0.56), (0.20, 0.31), (0.30, 0.17), (0.40, 0.08), (0.50, 0.04), (0.60, 0.03), (0.70, 0.02), (0.80, 0.01), (0.90, 0.01), (1.00, 0.00); Effect_of_Cash_Sufficiency_on_PM&E = GRAPH(Cash_Sufficiency_for_PM&E) (0.00, 2.50), (0.20, 1.93), (0.40, 1.55), (0.60, 1.34), (0.80, 1.15), (1.00, 1.00), (1.20, 0.92), (1.40, 0.88), (1.60, 0.84), (1.80, 0.81), (2.00, 0.80); Effect_of_PM&E_Capacity_Adequay_on_PM&E = GRAPH(Adequacy_of_PM&E_Capacity_for_Ongoing_Projects) (0.00, 2.50), (0.20, 1.71), (0.40, 1.38), (0.60, 1.18), (0.80, 1.06), (1.00, 1.00), (1.20, 0.94), (1.40, 0.87), (1.60, 0.84), (1.80, 0.82), (2.00, 0.80); Effect_of_PO_Capacity_Adequacy_on_PM&E = GRAPH(Adequacy_of_PO_Capacity_for_PM&E) (0.00, 2.00), (0.20, 1.66), (0.40, 1.43), (0.60, 1.23), (0.80, 1.09), (1.00, 1.00), (1.20, 0.92), (1.40, 0.88), (1.60, 0.85), (1.80, 0.82), (2.00, 0.80); Effort_in_Winning_New_Projects = Total_Appetite_for_New_Projects*Effect_of_Adequacy_of_PO_Capacity_for_Effort_in_WNP

Entrepreneural_Drive = 2; Equity = (Cash_Availability+Working_Capital+Accounts_Receivable+0.3*Cost_of_PM&E_Capacity+0.3*Cost_of_PO_Capacity)-(Accounts_Payable+Loan); Equity_Investment = Proportion_of_Arranged_Equity_for_Indicated_Withdrawal*Indicated_Withdrawal_from_Equity Equivalent_Capacity_Needed_for_WNP_wrt_PM&E = .33; Estimated_Average_Turnover_per_Project_per_Month = 1000000

Expected_Average_Turnover_per_Project = RANDOM(24000000,30000000); Expected_Profit_Margin = 0.1; Expected_Profit_per_Month = Expected_Profit_Margin*SMTH1(Total_Turnover_per_Month, 12); Expected_Turnover_from_Incoming_Projects_per_Month = Expected_Average_Turnover_per_Project*Project_Internalisation; Fractional_CfM_for_Subs = 0.02; Fractional_CfM_for_the_Company = 0.1; Fractional_Cost_for_PM&E_Capacity_Acquisition = Proportion_of_Actual_Project_Cost+Proportion_of_Actual_Direct_OC

Fractional_Cost_for_PO_Capacity_Aquisition = Proportion_of_Actual_Indirect_OC; Fractional_Depletion_of_Clientele = 0.001

Fractional_PM&E_Capacity_for_Ongoing_Projects = 1; Fractional_Retention_Amount = .1; Fractional_Retention_Amount_from_Subs = .1

Fractional_Turnover_Allcoated_for_PO_Capacity_Acquisition = 0.1; Fractional_Turnover_Allocated_for_PM&E_Capacity_Acquisition = 0.05; Indicated_Borrowing = (Proportion_of_Deficiency_Borrowing*Cash_Deficiency) Indicated_Budget_for_PM&E_Capacity_Acquisition =

Indicated_PM&E_Capacity_for_Ongoing_Projects*Estimated_Average_Turnover_per_Project_per_Month*Fractional_Turnover_Allocated_for_PM&E_Capacity_Acquisition; Indicated_Budget_for_PO_Capacity_Acquisition = (Indicated_PO_Capacity_for_WNP+Indicated_PO_Capacity_for_PM&E)*Estimated_Average_Turnover_per_Project_per_Month*Fractional_Turnover_Allcoated_for_PO_Capacity_Acquisition; Indicated_Cash_Requirement_for_Indirect_Overhead = Ongoing_Projects*Estimated_Average_Turnover_per_Project_per_Month*Proportion_of_Indirect_OC_Normal Indicated_Cash_Requirmeent_for_Direct_Overhead = Ongoing_Projects*Estimated_Average_Turnover_per_Project_per_Month*Proportion_of_Direct_OC_Normal Indicated_PM&E_Capacity_for_Ongoing_Projects = Ongoing_Projects*Fractional_PM&E_Capacity_for_Ongoing_Projects

Indicated_PO_Capacity_for_PM&E = Ongoing_Projects; Indicated_PO_Capacity_for_WNP = Potential_Projects*Equivalent_Capacity_Needed_for_WNP_wrt_PM&E; Indicated_Withdrawal_from_Equity = (1-Proportion_of_Deficiency_Borrowing)*Cash_Deficiency; Initial_Estimated_Completion_Time = 24; Interest_Rate = 0.06/12

Market_Reputation = GRAPH(Adverse_Impression_in_Market) (0.000, 1.0000), (0.100, 0.5940), (0.200, 0.3796), (0.300, 0.2532), (0.400, 0.1420), (0.500, 0.0930), (0.600, 0.0570), (0.700, 0.0360), (0.800, 0.0260), (0.900, 0.0180), (1.000, 0.0100) Monthly_Deductible_Amount_of_CfM_for_Subs = CfM_for_Subs/Average_Time_of_Engagement_for_Subs Monthly_Deductible_Amount_of_Compensation_for_Mobilisation = Total_CfM_to_be_Received_per_Month/Initial_Estimated_Completion_Time

Net_Average_Cost_of_Ongoing_Projects_per_Month = Total_Average_Cost_of_Ongoing_Projects_per_Month-CfM_for_Subs

Net_Payments_to_be_Made = Net_Average_Cost_of_Ongoing_Projects_per_Month/Average_Time_to_Make_Payments_to_Subs_and_Suppliers Net_Turnover_per_Project_per_Month = Total_Turnover_per_Month-Total_Deductible_Retention_Amount_per_Month-Monthly_Deductible_Amount_of_Compensation_for_Mobilisation; Normal_Project_Completion_Time = RANDOM(24,30)

Number_of_other_Potential_Clients_per_Completed_Project = 2; Observed_Profit_Achievement_Ratio = SMTH1(Profit_Achievement_Ratio, 24); Other_Potential_Projects_in_Market = GRAPH(TIME) (1.0, 204.5), (12.92, 217.0), (24.83, 248.9), (36.75, 236.2), (48.67, 193.6), (60.58, 217.0), (72.5, 234.0), (84.42, 219.1), (96.33, 202.1), (108.25, 189.4), (120.17, 242.6), (132.08, 206.4), (144.0, 189.4) PM&E_Capacity_Adjustment_Delay = 6; PM&E_Capacity_Deployment = 0.9; PO_Capacity_Adjustment_Delay = 6

PO_Capacity_Dedicated_for_PM&E = Project_Operations_Capacity-PO_Capacity_Dedicated_for_WNP; PO_Capacity_Dedicated_for_WNP = Project_Operations_Capacity*Proportion_of_PO_Capacity_Dedicated_for_WNP

PO_Capacity_Deployment = .9; Potential_Projects = (Clientele+Other_Potential_Projects_in_Market)*Market_Reputation

Profit_Achievement_Ratio = Actual_Profit/Expected_Profit_per_Month; Proportion_of_Actual_Direct_OC = Proportion_of_Direct_OC_Normal*Effect_of_Adequacy_of_Capacities_and_Cash_Sufficiency_

on_Costs Proportion_of_Actual_Indirect_OC = Proportion_of_Indirect_OC_Normal*Effect_of_Adequacy_of_Capacities_and_Cash_Sufficiency_on_Costs

Proportion_of_Actual_Project_Cost = Proportion_of_Expected_Project_Cost_Normal*Effect_of_Adequacy_of_Capacities_and_Cash_Sufficiency_on_Costs

Proportion_of_Actual_Total_Cost = Proportion_of_Actual_Project_Cost+Proportion_of_Actual_Direct_OC+Proportion_of_Actual_Indirect_OC

Proportion_of_Arranged_Equity_for_Indicated_Withdrawal = 1; Proportion_of_Deficiency_Borrowing = 0 Proportion_of_Direct_OC_Normal = .1; Proportion_of_Expected_Project_Cost_Normal = 1-(Expected_Profit_Margin+Proportion_of_Direct_OC_Normal+Proportion_of_Indirect_OC_Normal); Proportion_of_Indirect_OC_Normal = 0.05; Proportion_of_PO_Capacity_Dedicated_for_WNP = .2; Proportion_of_Profit_Allocation_for_Dividends = .3 Proportion_of_RE_for_Reinvestment = 1-Proportion_of_Profit_Allocation_for_Dividends; Rate_of_Attrition_of_PM&E_Capacity = 0.01

Rate_of_Attrition_of_PO_Capacity = 0.01; Received_CfM_Amount = Total_CfM_to_be_Received_per_Month/Time_Taken_to_Receive_the_CfM_Amount; Required_Cash_per_Month_for_PE = Ongoing_Projects*Estimated_Average_Turnover_per_Project_per_Month*(Proportion_of_Direct_OC_Normal+Proportion_of_Indirect_OC_Normal+Proportion_of_Expected_Project_Cost_Normal); Return_on_Equity = Retained_Earnings/Equity

Time_Required_to_Archive_Failed_Projects = 1; Time_Required_to_Archive_Successful_Projects = 1 Time_Required_to_Internalise_Projects = 1; Time_Required_to_Win_a_Project = 6; Time_Taken_to_Arrange_Borrowing = 3

Time_Taken_to_Receive_the_CfM_Amount = 1; Time_to_Collect_the_Turnover_Amount = 1; Time_to_Deploy_PM&E_Capacity = 1

Time_to_Make_Decision_about_Project_Abandonment = 24; Time_to_Make_Payments = 1; Total_Appetite_for_New_Projects = Base_Appetite_for_New_Projects*Entrepreneural_Drive; Total_Average_Cost_of_Ongoing_Projects_per_Month = Total_Turnover_per_Month*Proportion_of_Actual_Project_Cost; Total_CfM_to_be_Received_per_Month = Project_Internalisation*Compensation_for_Mobilisation_Costs_per_New_Project; Total_Deductible_Retention_Amount_per_Month = Fractional_Retention_Amount*Total_Turnover_per_Month; Total_Retention_Amount_per_Month_from_Subs = Fractional_Retention_Amount_from_Subs*Total_Average_Cost_of_Ongoing_Projects_per_Month Total_Retention_Amount_to_be_Paid_per_Completed_Project_per_Month_to_Subs = Total_Retention_Amount_per_Month_from_Subs/Completed_Projects; Total_Turnover_per_Month = (Project_Execution*Expected_Average_Turnover_per_Project)

{The model has 167 (167) variables (array expansion in parens) ; In root model and 0 additional modules with 4 sectors.; Stocks: 17 (17) Flows: 31 (31) Converters: 119 (119); Constants: 42 (42) Equations: 108 (108) Graphicals: 13 (13)

There are also 25 expanded macro variables.}