A DYNAMIC POLICY MODEL TO MANAGE TEMPORAL PERFORMANCE AMONGST CONTRACTING FIRMS IN A COMPETITIVE SITUATION

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Studies have been conducted to measure competitiveness in the construction industry. Such research has focused on all levels from the national picture to individual projects. While useful, the results are limited in that they present a snapshot picture at one point in time. Moreover, they do not suggest how under-performance might be improved. The research reported here is part of a large collaborative study to evaluate sustained competitiveness in the UK construction industry. It enhances previous research in that a system dynamics model of contracting firms operating in competition is used to not only measure each firm's temporal performance by means of a dynamic competitive index, but it can also suggest high leverage policies which mitigate against under-performance. The model structure is described and simulated scenario runs presented. Besides the contribution to strategic policy making at the level of the contracting firm, the exemplar shows that the system dynamics methodology could have significant utility in the field of construction management.

KEYWORDS: competitiveness; modelling; contracting; policy

INTRODUCTION

There has been an interest in competition and competitive advantage in the construction industry since the early 1990's. Flanagan et al (2007) in their review paper list their earliest references from that period as those of Male and Stocks (1991) and Drew and Skitmore (1992). In business and management research generally, work at least a decade earlier can be cited (Porter, 1980), whilst the concern is undiminished even in the new millennium (Cockburn, Henderson and Stern).

Flanagan et al's (2007) review points out that research has been undertaken at three levels: that of the industry, the firm and the individual project. It is at the firm level where sustaining competitiveness is most crucial, for while under-performance on one project may be something which an individual firm may recover from – by dint of compensating strong performance on other projects – the firm is the legal entity and failure at this level may predicate liquidation.

Research on competitiveness inevitably hits an immediate problem in deciding how to actually measure this most abstract and ill-defined of concepts. Lu (2006) has proposed an index and this is the basis of a computer program which has been used to diagnose contractors' competitiveness and to place them in rank order of competitiveness. It is a system suitable only for Chinese general contractors according to Flanagan et al. Similarly Sha, Yang and Song (2008) provide an index which is used to measure the competitiveness of the Chinese construction industry in various provinces.

All this work either provides a conceptual and theoretical basis for the consideration of competitiveness or provides an assessment of the magnitude of an individual unit's competitive strength at a single point in time. What this does not do however is suggest to firms how, if they are shown to be under-performing, they can improve their situation. There is a need to move on from understanding and measuring competitiveness to improving it. The research reported below is one small step towards making this advance.

The employment of an industrial steering committee that meets and reviews the progress of the research, quarterly over the research period, has assisted in forging engagement with the industry. There is a requirement for a high level of engagement due to the rapid and often dramatic changes which occur in the construction sector. Whilst literature reviews and past studies can shed light on historical circumstances and firm structure they do little to show the present strategies of leading industrialists. Through workshops, interviews and questionnaires real-time factors affecting the industry can be taken into account when scenario testing the models.

A DYNAMIC MODEL FOR CONTRACTORS' OPERATIONS

If there is a desire to assess a firm's performance and, if deficient, to suggest how they might improve it, then one way forward is to design a model which reflects a competitive situation and allows performance of an individual constituent entity (a contracting firm in this case) to be changed by dint of changed policies. To this end a generic contractors' model has been formulated. The model incorporates three stylised general contracting firms, A-C, in competition (although any number of competitors could have been used). The methodology allows various resources to be modelled – materials, money, people – but, moreover, also considers the policies which govern the management of these resources which, in turn, determines the firm's competitive strength. The model, when run, dynamically traces out the performance of individual variables over a period of time. If a firm is under-performing then it's 'competitors' can react and secure a further advantage.

The purpose of this study is to assess policy issues and highlight those which might result in a sustained performance, as opposed to policies which might predicate intermittent crises. The model does not purport to produce a 'forecast' of what might happen in to a real-life construction firm, but rather is an instrument of learning – to suggest how some policies can lead to competitive benefits whilst others are deficient or capable of producing unexpected behaviour. The notional contracting firms are generic although their structure mimics typical firms in the industry and both that and the model's parameters have been determined through literature searches and interviews with industry executives. It is proposed to launch a questionnaire to selected industry members in order to further extend our knowledge on crucial parameter values. Although the firms are generic, it would be perfectly possible to parameterise one of them to equate with a particular real-world contracting firm.

A High-level map

A representation of the overall view of the model in the form of a high-level map is depicted in figure 1. It shows that the typical contracting firm must manage human resources, money and materials. Its performance is affected by its competitor's actions but, aside from them, there are issues which affect a firm's reputation and which in turn have largely been determined by its own actions. These include control of project over-runs, late starts and financial shortfalls. These sorts of issues affect a contracting firm's competitive position and thus its ability to win further contracts in the market place.

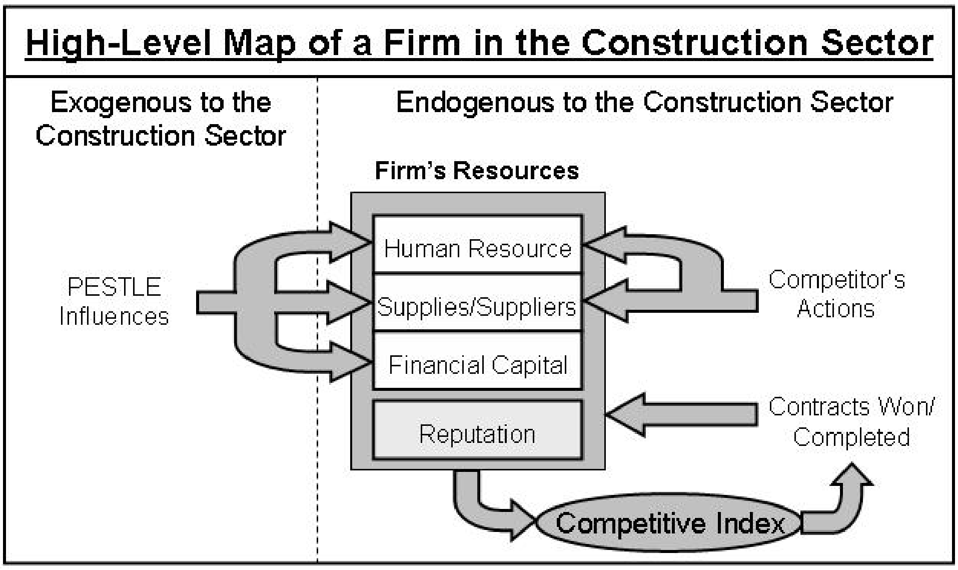

Figure 1: High-level map of a generic firm in the contractors' model

On top of the internal management issues there are exogenous influences which all the competing contracting firms have to face. These can have an impact on all of the firm's resources and range from Chinese economic development impacting on the world demand for construction steel through to governmental regulatory legislation directly targeted at the industry.

The Competitive Index

The factors affecting a contracting firm's reputation are handled in the model by the establishment of a competitive index. This is a means to embrace the range of factors which impact on competitiveness and implicitly recognises that the concept it is a multi-dimensional one. The references to Lu (2006) and Sha, Yang and Song (2008) in respect of the Chinese construction industry reveal that this is not a new idea. But whereas their index formulations are used on construction industry data, ours is embedded in a dynamic model and so is continually being re-computed 'on the fly' as the simulation proceeds.

The design of our competitive index is as depicted in figure 2 for a single contracting firm. The spokes leading to the central ellipse are competitive factors (CF) each of which contributes to the calculation of the overall competitive index (CI) for that firm, although they can be each assigned different weights (W). The spoke lengths are variable reflecting the strength of that factor at varying points in time. Lengthening of the spoke length may reflect an improved performance if the competitive factor was, say, revenue and a deteriorating performance if it reflected a late completion time on the contract. These spoke lengths can and do vary as the model simulation proceeds through time. The weights on the other hand will not: they reflect the relative importance of each competitive factor in the given market. This is emphasised by the diameter of the nodes representing the weights at the end of each spoke. It would be perfectly feasible to adopt this particular mechanism for assessing competitiveness in other industrial or commercial situations, apart from construction.

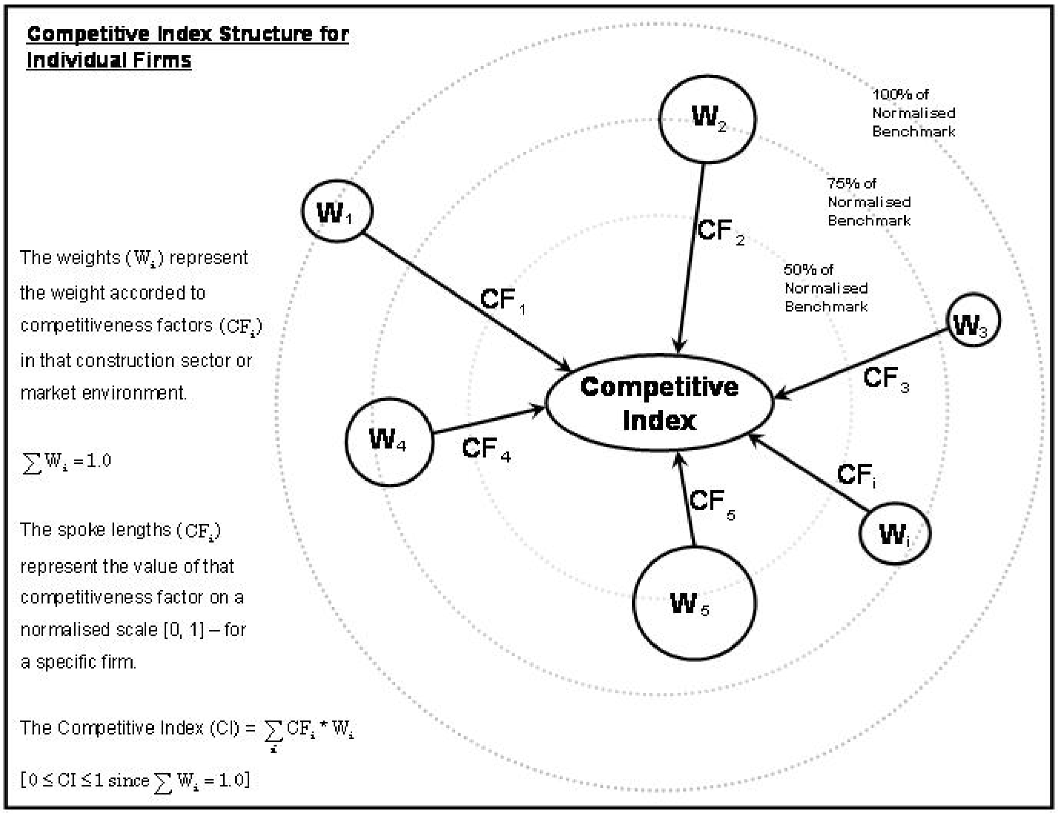

Figure 2: Diagrammatic representation of the competitive index as used in the model

The weights are constrained to sum to 1.0 and the value of each competitive factor is normalised to a scale of 0-1.

Sum of the weights:

$$\sum W_i = 1.0$$

This is achieved by determining the best (largest or smallest as appropriate) of the three competing firm's values for a given CF and awarding this the value of 1.0, e.g. for finance this would be computed as:

Normalised Financial Resource[Firm] =CashBalance[Firm] / VMAX(CashBalance[Firm!])

The other (two) values are then calculated as pro-rata values against the best value. This is the mechanism used by the World Bank to determine the competitiveness of different nations. It should be noted that this is not the same normalisation process as that adopted by Sha, Yang and Song (2008). Theirs ensures that the full range of the scale is used. Thus, under their method, one firm will always score 0 and another 1.0 on any given competitive factor.

Our method allows one to determine how far off the 'best' any given firm is for any given competitive factor. For instance, it can be seen that the hypothetical firm depicted in figure 2, for this particular point in time, scores the best for competitive factor 1 but is only at 75% of the normalised benchmark for CF's 2 and 4. It performs worst on CF 5 where it is at only 50% of the normalised benchmark.

The competitive index (CI) is the weighted sum of the individual weights times the normalised values of each competitive factor. It must result in a value in the range of 0 to 1.0 and is re-computed at every time step in the simulation. A firm will be awarded contracts in proportion to its CI value over the sum of all firms' CI values.

Competitive index for each firm:

$$\sum_i CF_i * W_i$$

In this way its 'reputation' is fed back into its ability to secure future contracts. It should be understood that this means that if all of the firms have the same CI (whether that be, say, 0.33, 0.5. 0.6 or indeed 1.0) they will each receive the same share of the contracts on offer in the market: one-third in this case.

The sectors of the model

The model has three main sectors: contracts and work-in-progress; finance; and human resources. The first of these is shown in figure 3. Although there are assumed to be three competing firms in this market the diagrammatic representation is common.

Two policy domains which are suggested by a consideration of figure 3 are, firstly, the allocation of contracts and whether to bid aggressively or take a measured view on future undertakings. Another obvious policy consideration surrounds the management of work-in-progress. These two intervention points are illustrated in figure 4. Under-performance in the management of work-in-progress will result in late contract completion – a major factor determining a contractor's reputation.

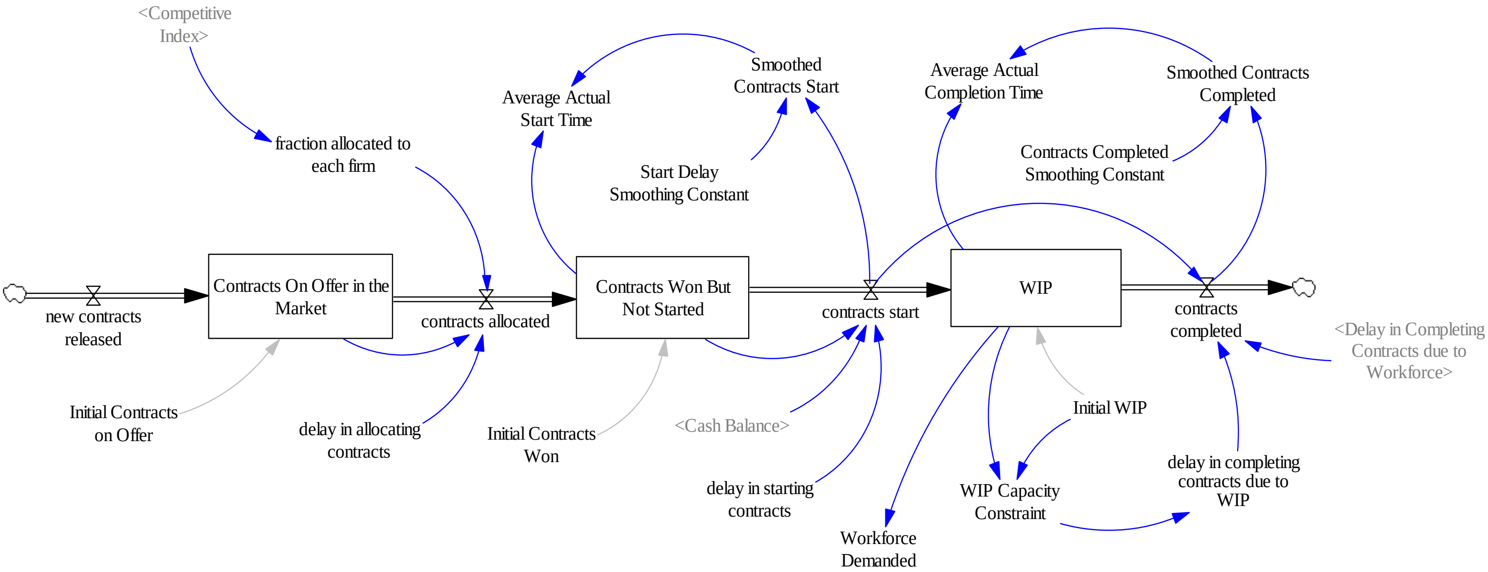

Figure 3: Stock and Flow diagram of the contracts and work-in-progress sector

STRATEGY ANALYSIS FOR A CONTRACTOR

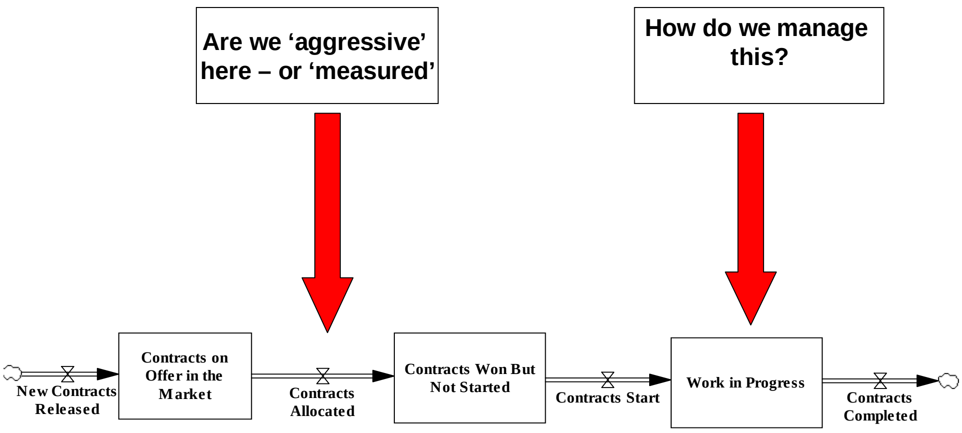

Figure 4: Intervention points in the Contractors model

The fraction of contracts allocated to each firm is, in a raw bidding process, determined by the competitive index as described above. Within the model the influences on this are as illustrated in figure 5. These number four: completion delay; start delay; financial factors; and workforce factors.

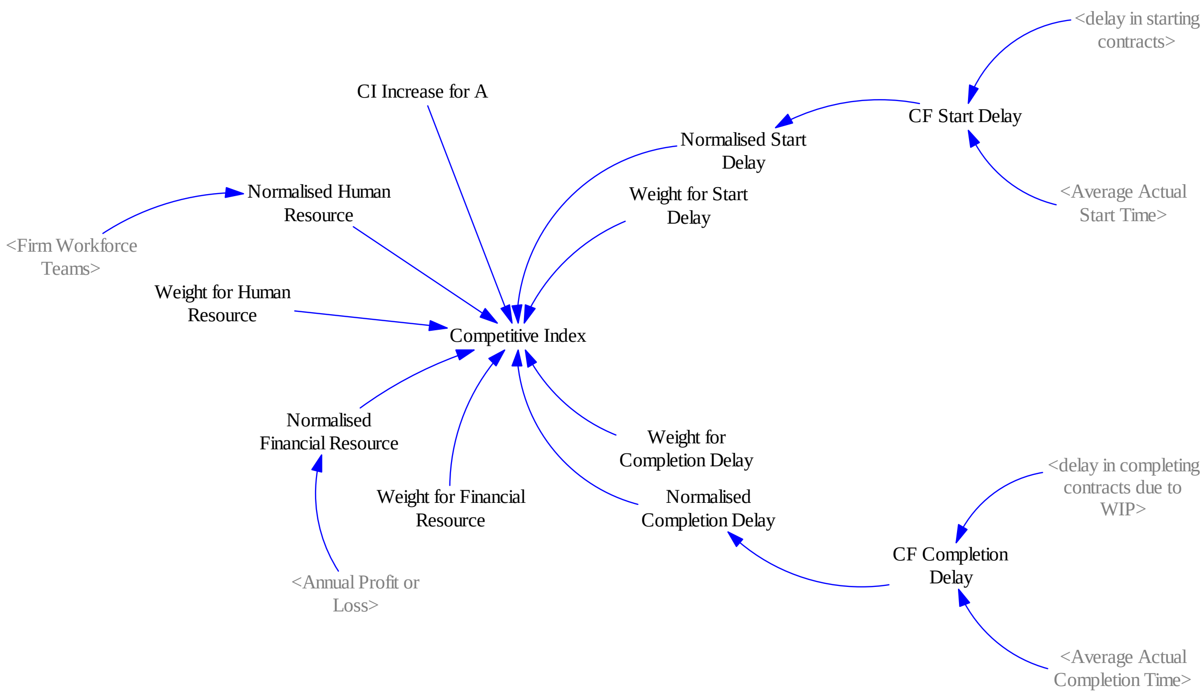

Figure 5: Influences on the competitive index in the model

The time taken to both start and complete contracts affects the reputation of the firm. A delayed project will reduce the number of contracts allocated to that firm in the future. With fewer contracts allocated to a firm they "should" perform better then competitors with a higher number of contracts to complete, leading to a higher proportion of the newly allocated contracts. These two balancing loops are complicated by both the actions of competitors and additional factors present in the model.

The remaining sectors consist of (i) finance and (ii) human resources including those employed directly by the firm and those sub-contracted.

The financial sector is simply revenue in: costs out arrangement, although fresh accumulations are made each year to mimic the normal annual financial reporting period. The simulations cover a period of 15-20 years and the fixed time step is one-eighth of a year. The parameter values currently adopted in the model are listed in table 1. Obviously these can be changed very easily; indeed a parameter change may form a component of a strategic policy experiment.

Human resources in construction firms refer to both those employed directed by the firm and those employees sub-contracted out. Typically, directly employed staff are more expensive than sub-contracted workers, due to having to pay for them whilst they are under-utilised and their training, national insurance and pension requirements. The benefit in having directly employed staff is the reduction in time when employees are required onsite or training. Any gaps between the supply and demand for human resources are reduced by both sub-contracted and directly employed staff, though the model view (figure 6) gives a greater competitive factor score to the firm with the higher proportion of directly employed staff.

Table 1: Listing of Parameters in the model and their assumed values

Parameter Values

The following are the main parameter values in the model:

- Money in takes 28 days with money out takes 35 days (holding money for 7 days).
- Change the delay terms may be confusing (get more in tune with industry parlance).
- £10 million job in one year is comfortable (£1 million a month)
- Mobilisation period not 1.5 years, 2months is better. It was suggested that the parameter values should be changed
- Hiring lag, very short (2 weeks)
- On average there would be approximate 50 people working on site
- £40,000 would be the average salary
- Materials could be 35% of the contract sum
- Labour costs 7-8%

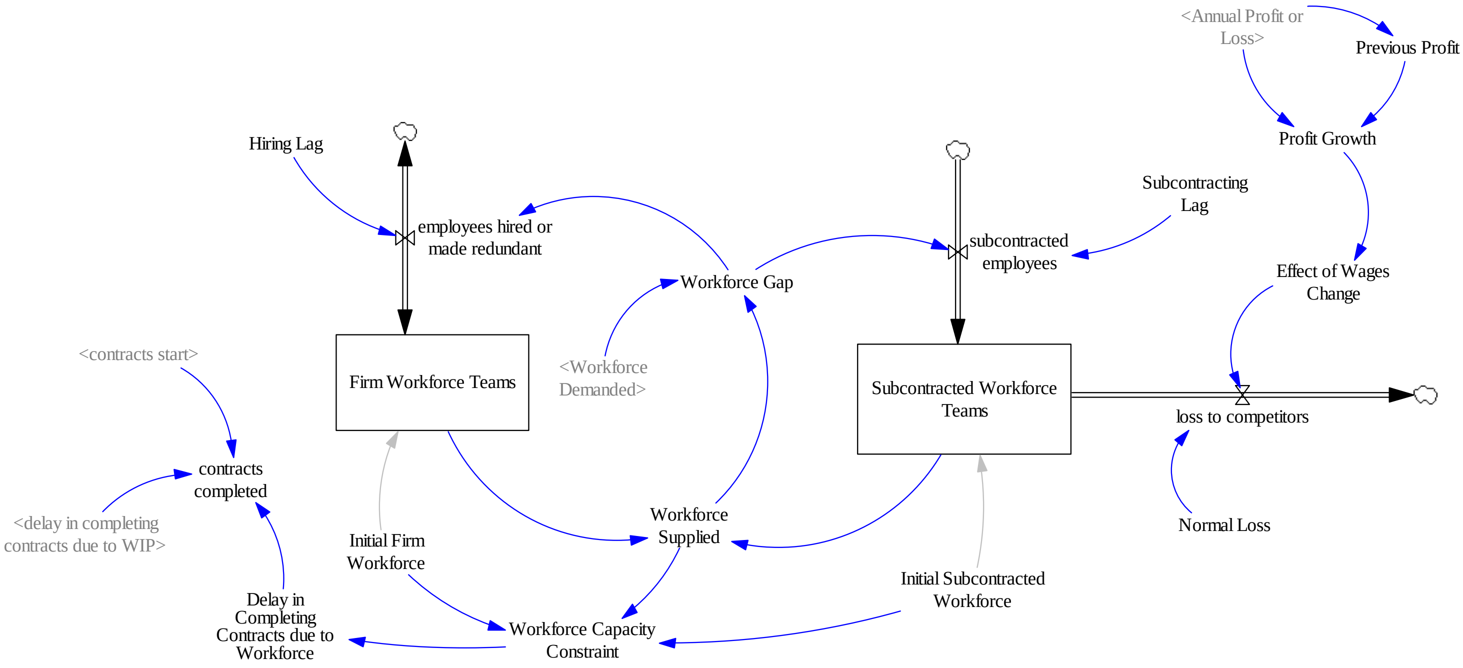

Figure 6: Human Resources stock and flow view

Another interesting aspect of the human resources is that of "teams". Contracts are often completed by a dedicated team, who complete one contract before moving onto the next project/contract.

DEPLOYMENT OF TEAMS

	Large team	Small Team
Large contract	OK	Problems
Small contract	OK but losses	OK

Figure 7: The dilemma associated with operating using specialist teams

These teams are used most often on specialist projects or larger contracts. When employed on suitable projects the teams are profitable. However, when these teams are employed on unsuitable projects there are two problems. The first problem is that the team is perhaps forced to operate at a lower profit margin or even a loss. The second problem is that any large contracts won by a firm with a small team will be late in starting due to the team taking extra time to gear up for the project – maybe more members would need to be recruited. This second problem can also reduce or eradicate the potential profits. See figure 7.

Specialist teams are required and make more profit when used on suitable projects and most firms agree that they need to employ and manage such teams. The creation of such teams is driven by profitability (figure 8).

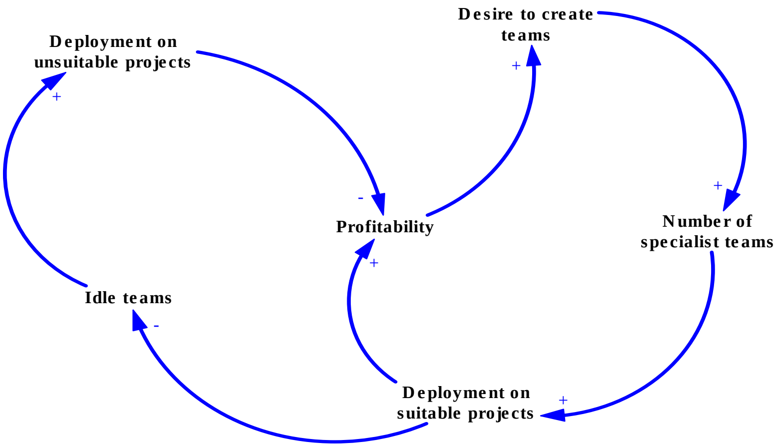

Figure 8: The Profitability of Specialist Teams

Construction firms typically make only 3% profit on a contract. The mismanagement of a team can easily eliminate the profits of a construction firm, not just for one project but the year. One scenario we propose to investigate is the strategic decision to employ specialist teams on unsuitable projects compared with keeping the teams idle, which costs more. Clearly, employing the teams on unsuitable projects is the correct decision when there are no suitable projects due to be allocated. It is unclear, however, how these "saved costs" compare with "missed profits" through delaying the start of a project and thus affecting the competitive index.

RESULTS FROM SPECIMEN SCENARIO RUNS

The research is a work-in-progress and so the following details some of the experiments which have been carried out to date.

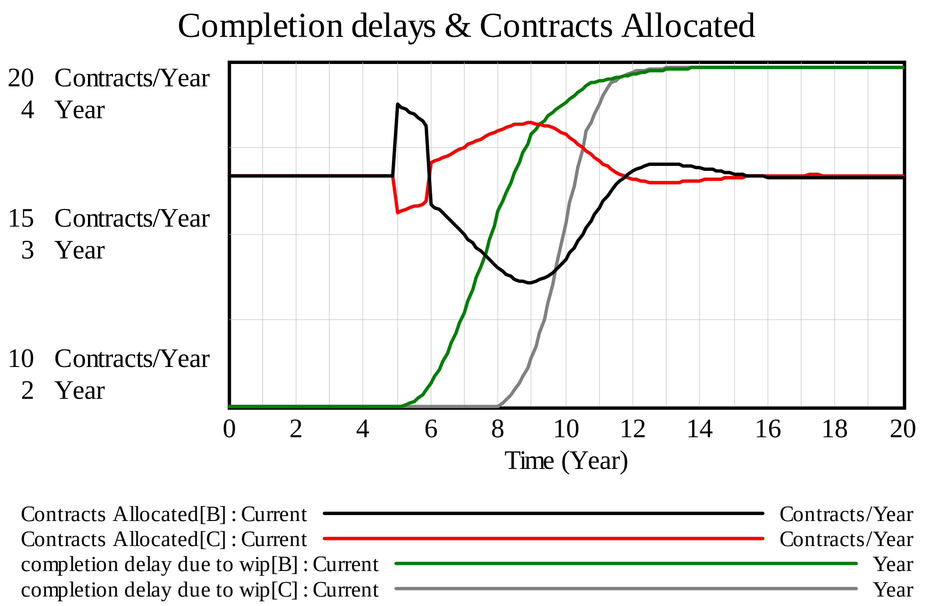

Figure 9: Effects of competitive stimulus on completion delays and contracts allocated

Consider figure 9. Here the contracting firm B is arbitrarily given a temporary boost to its competitiveness after a short initial period of equilibrium throughout which no dynamics are evident. The disturbance allows an assessment of the repercussions of a firm seemingly exceeding the short-term performance of its main competitors. Note that we are not trying to reproduce some real-world occurrence but rather provide a laboratory setting where strategic conclusions can be reached without resorting to a real-world experiment, the outcome of which might take many years to determine.

In figure 9 the success of firm B is evident: they have brought in more contracts in view of the arbitrary stimulus to their competitive index. However, this success does not last and a downturn is evident from around one year later. (Note that Firm A's plot is superimposed by that for Firm C since no differentiation is attempted between these two firms.)

The reason for Firm B's transient superiority is because it becomes overwhelmed by work-in-progress and the initial stimulus is reversed, primarily because of its poor performance in completing contracts. It hits its capacity limit and the delays in completion rise far earlier than for firms A and C. Theirs do start to rise after they profit from B's failings, however, and the momentum then returns to a newly rejuvenated firm B. The strategic message has to be that capacity management is vital if a contracting firm is to experience sustained and not transient competitiveness. It is worth emphasising that Firms A and C have experienced an upturn over a three year period up to year 9 purely because Firm B has become uncompetitive. These other two firms have not been proactive but have simply benefited from B's poor policies on capacity. See also figure 10.

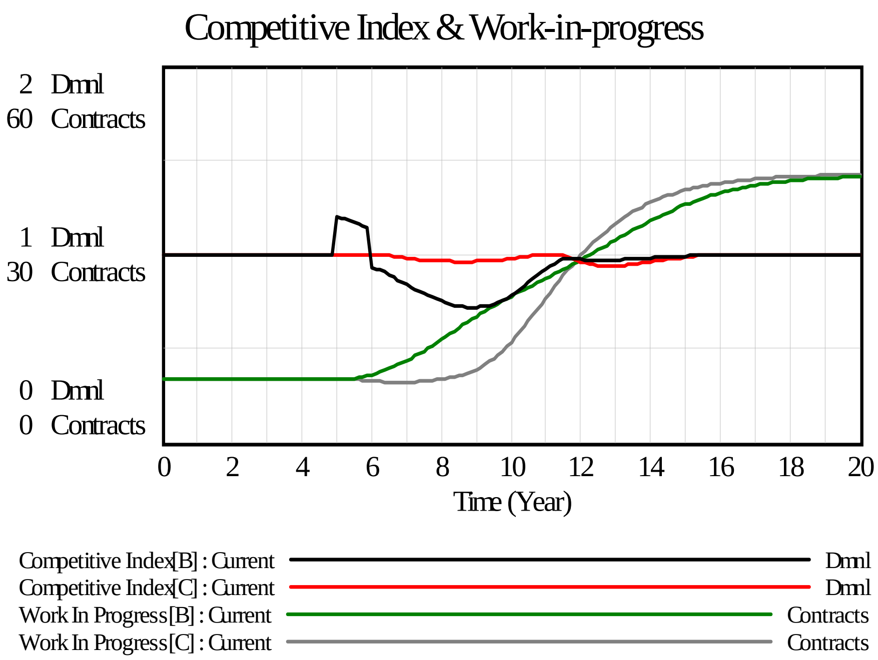

Figure 10: Firm B's Competitive Index is made worse than the other firms as its work-in-progress increases; firms A & C benefit eventually forcing up their own work-in-progress

Finally a comparison plot shown as figure 11 reveals an all-too-common conclusion from competitive dynamics. As the aggressive competitive behaviour increases – aggressive bidding and willingness to undertake litigation in defence of performance – so does the volatility of the system and in particular it has a deleterious effect on profits. A phrase used was by one manager was that it represented the 'hunter-gatherers' in the industry versus the 'farmers'. The latter are characterised by taking a more measured approach to gaining new business, such as via the concept of 'frameworks' where a series of linked projects are offered by a single client. It commonly constitutes an emphasis on good market research and putting value ahead of profit.

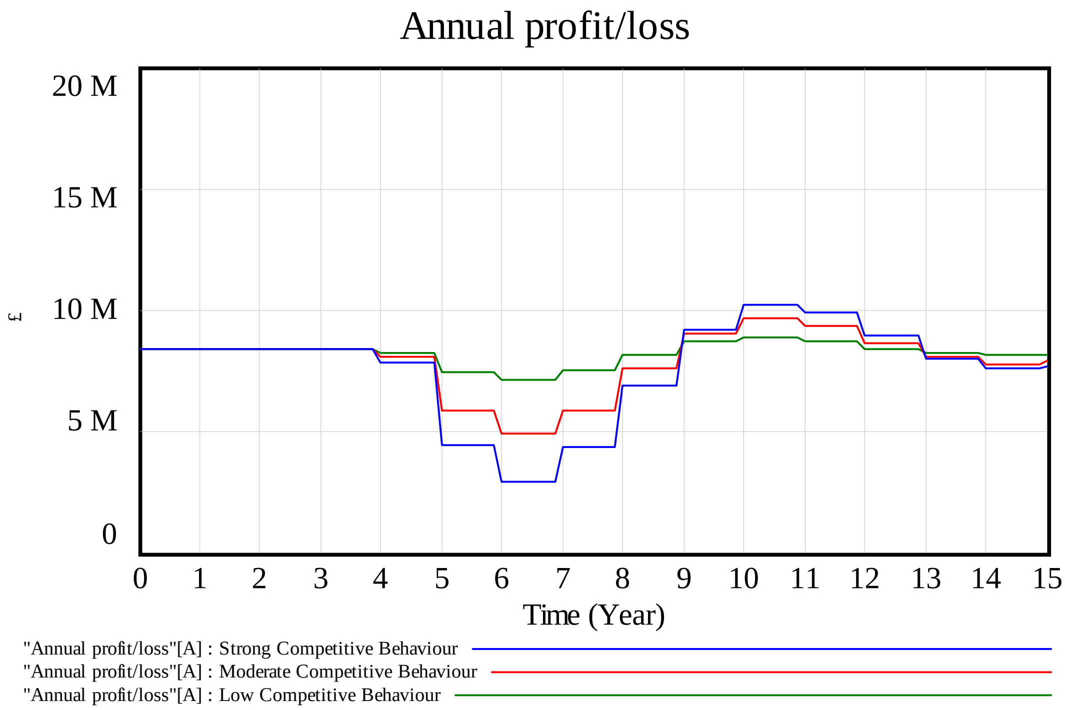

Figure 11: Aggressive competitive behaviour increases the volatility of the system

MODEL VALIDATION

As this is a generic model an appropriate way to ascertain the model's validity is to expose it to a panel of representative managers who work or have worked in the industry. After taking a group of experienced managers through the various aspects of the model structure and exposing them to just a few of the runs we had conducted, we posed the following three questions:

- Do you think there are any fundamental flaws in the model as shown?
- Is there anything which needs adding to the model?
- Specify up to three issues or causes of concern which the model might be used to explore.

Not surprisingly parameter values were prominent in the early responses and it took some moments before focus could be concentrated on the structure. It proved a worthwhile session for amongst the responses was the notion of 'teams' as discussed earlier, together with the view that, in a recession, it would be easier to adjust the business volume if there was more subcontracting being undertaken, rather than employing labour directly.

CONCLUSIONS

The system dynamics methodology has been shown to be capable of providing a means to assess the forces which shape sustained competitiveness and, as such, it takes the assessment of strategic policy analysis in the construction sector onto a higher plane. The need to collect data and make retrospective assessments of competitiveness and strategic performance at the statistical level is not now the only *modus operandi* available. Models which capture the causative factors operating in the real-world and allow of easy experimentation offer a new paradigm for research on construction sector performance.

REFERENCES

Drew, D.S. and Skitmore, R.M. (1992) Competitiveness in bidding: a consultant's perspective. Construction Management and Economics, 10(3), 227-247.

Cockburn, I.M., Henderson, R.M., and Scott, S. (2000) Untangling the Origins of Competitive Advantage. Strategic Management Journal 21:(10-11), 1123-1145.

Flanagan, R., Lu, W., Shen, L., and Jewell, C. (2007) Competitiveness in Construction: a critical review of research. Construction Management and Economics, 25(9), 989-1000.

Lu, W.S. (2006) A system for assessing and communicating contractors' competitiveness. Unpublished PhD thesis, Department of Building and Real Estate, Hong Kong Polytechnic.

Male, S. and Stocks, R. (1991) Competitive Advantage in Construction. Butterworth-Heinemann, Surrey.

Porter, M.E. (1980) Competitive Strategy: Techniques for Analysing Industries and Competitors. Free Press, New York.

Sha, K., Yang, J., and Song, R. (2008) Competitiveness assessment system for China's construction industry. Building Research and Information, 36(1), 97-109.