A dynamic policy model to manage temporal performance amongst contracting firms in a competitive situation

Dangerfield, BC, Quigley, M and Kearney, JR

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

Brian Dangerfield
University of Salford, UK
b.c.dangerfield@salford.ac.uk

Michael Quigley
University of Salford, UK
m.quigley@salford.ac.uk

James Rhys Kearney
University of Salford, UK
j.p.r.kearney@pgr.salford.ac.uk

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 a simulated scenario run is 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, 2000).

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 (2007). 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.

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 using the methodology of system dynamics (Sterman, 2000). 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, determine 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 its '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 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 in this model 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 sort of issues affect a contracting firm's competitive position and thus its ability to win further contracts in the market place.

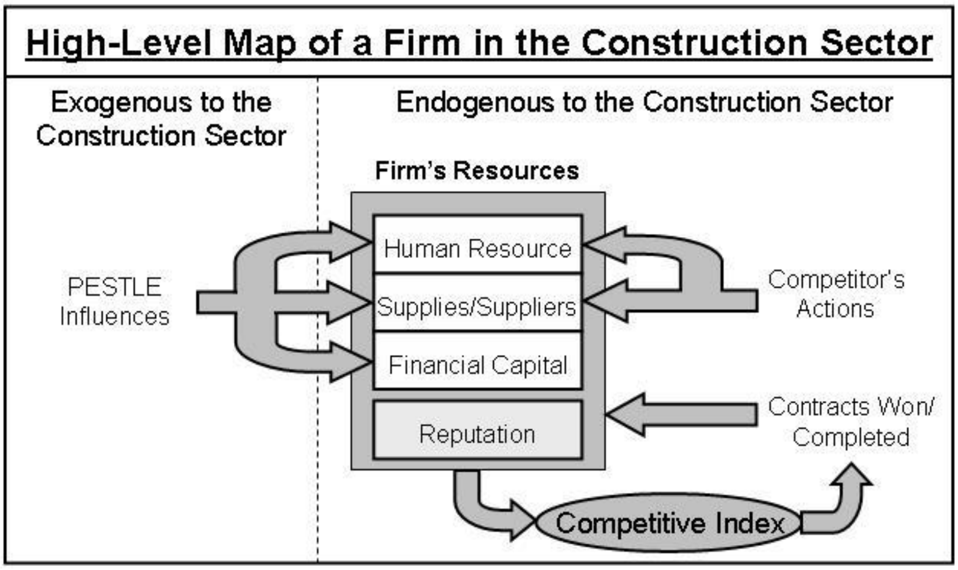

Figure 1: High-level map of a generic firm in the contractors' model

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 *ex post* 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 contribute to the calculation of the overall competitive index (CI) for that firm. The factors are each assigned 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.

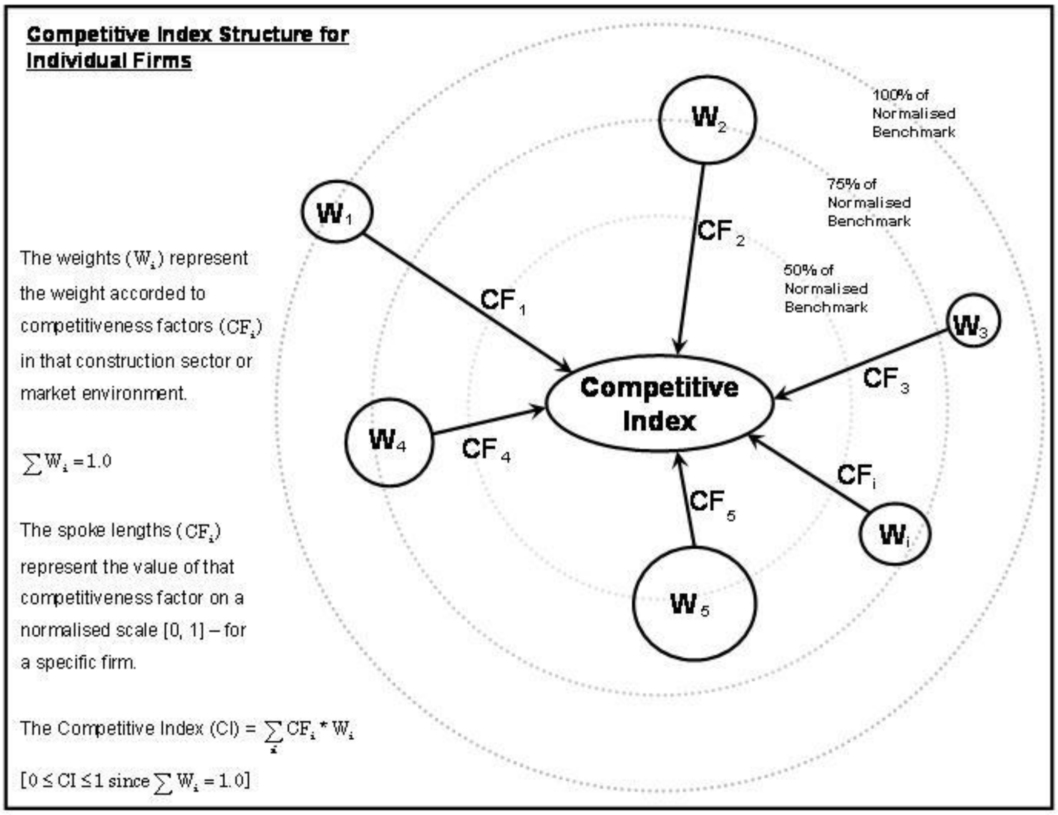

Figure 2: Diagrammatic representation of the competitive index as used in the model

The mathematics involved is highlighted in the figure. The weights are constrained to sum to 1.0 and the value of each competitive factor is normalised to a scale of 0-1. 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. 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 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 and this performance might prove costly since CF 5 has the largest weight. All of this assumes that, for all CF's, largest is best.

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.

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: the differing firms are handled by an array facility in the software employed. The rectangles represent stocks (accumulations) whilst the valve symbols depict management control and thus the policy leverage points. Raising or lowering a flow affects the stock immediately before and/or after it. 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. Under-performance here will result in late contract completion – a major factor determining a contractor's reputation.

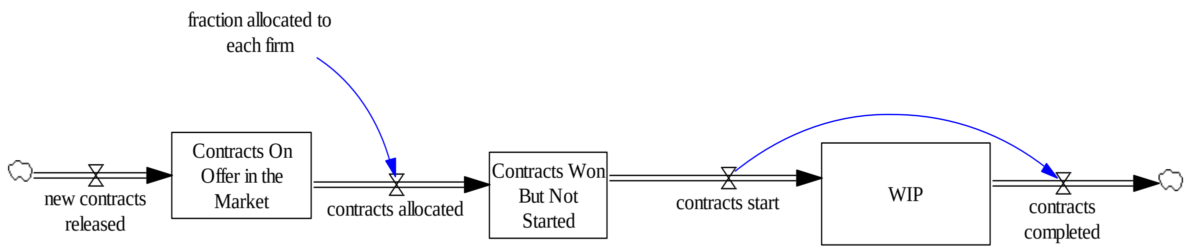

Figure 3: Flow diagram of the contracts and work-in-progress sector

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 4. These number four: completion delay; start delay; financial factors; and workforce factors.

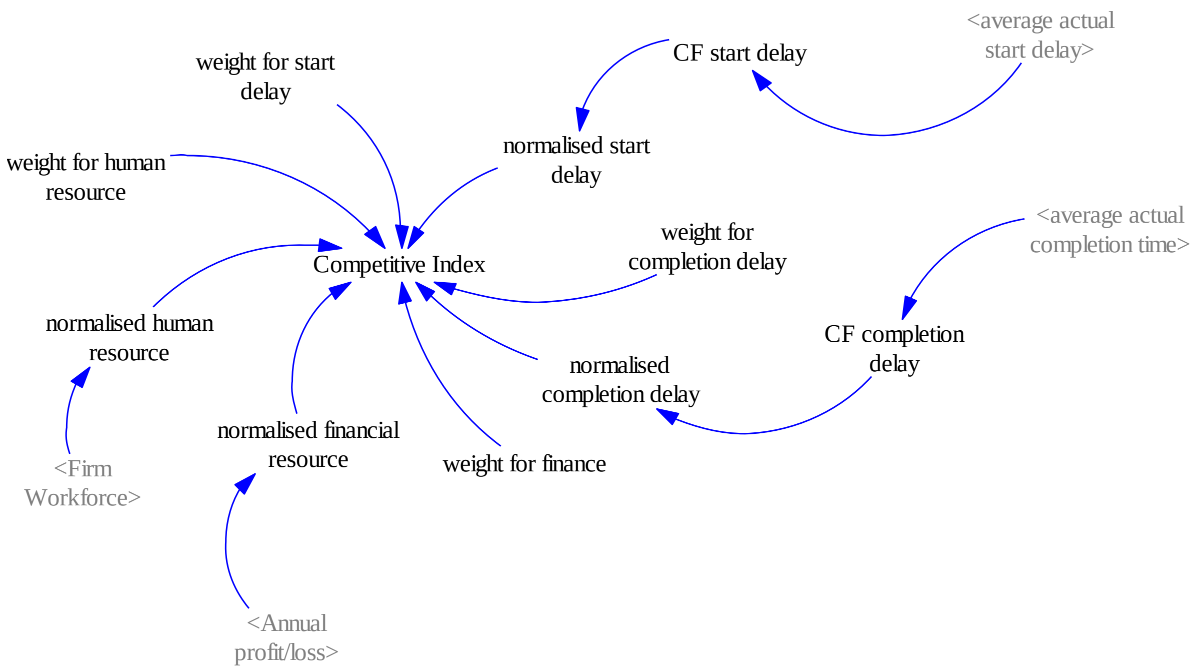

Figure 4: Influences on the competitive index in the model (Note: variables in angled brackets represent those computed in another model sector)

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 a revenue in : costs out arrangement, although fresh cumulations are made each year to mimic the normal annual financial reporting period. The simulations cover a period of 15 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.

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.

Consider figure 5. Here the contracting firm A is arbitrarily given a temporary boost to its competitiveness at time t=3. Before this time the model is in equilibrium and so 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 5 the success of firm A 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 B’s plot is superimposed on

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

Parameter Values

The following are the main parameter values in the model:

Delay in starting contract (normal)	1.5 years
Delay in completing contract (normal)	1 year
New contracts put on offer	50/yr
Hiring lag	1 year
Sub-contracting lag	3 months
Average number of employees on site (per contract)	50 people
Average revenue per contract p.a.	£4 million
Delay in receiving money	3 months
Delay in paying money	3 months
Average supply cost per contract p.a.	£0.5 million
Average cost per employee	£20,000 pa

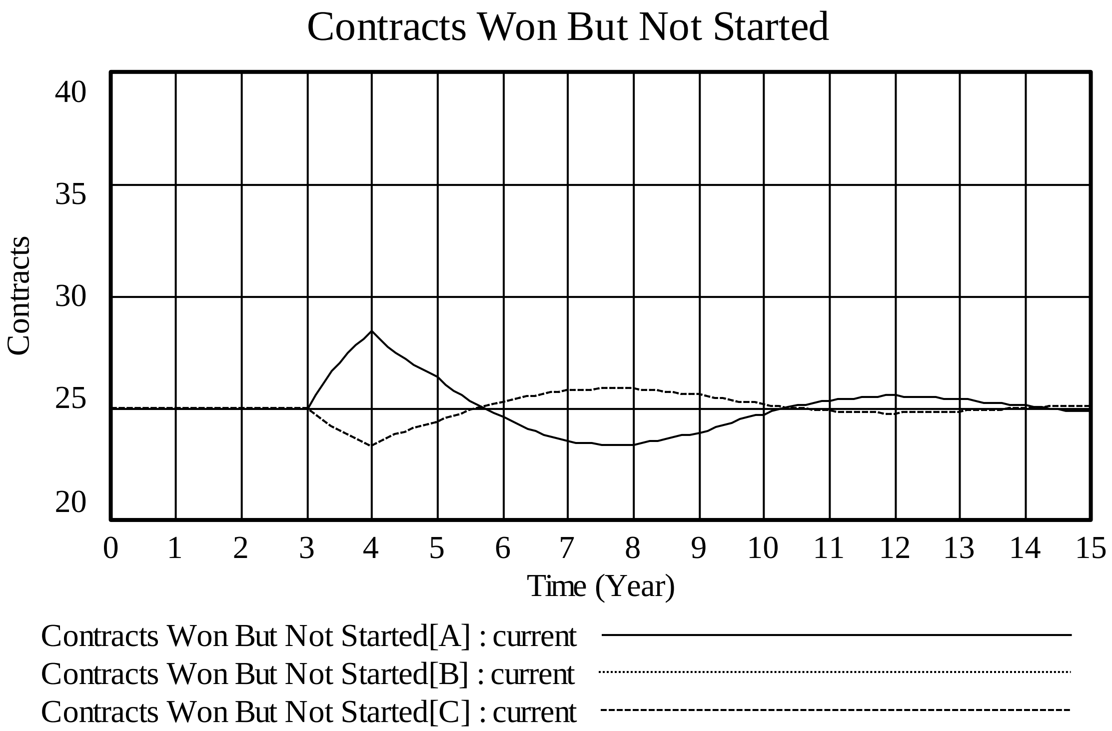

Figure 5: Effect of stimulus to Firm A on contracts won (NB 'Current' is the run name and is synonymous with 'Base Run')

that for Firm C since no differentiation is attempted between these two firms.) The reason for Firm A's superiority being merely transient is because it becomes overwhelmed by work-in-progress and the initial stimulus is reversed, primarily because of its poor performance in completing contracts (see figure 6). It hits its capacity limit. 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 noting also that Firms B and C experience an upturn in contracts won over a four-year period from year 4 purely because Firm A has become uncompetitive (figure 5). These other firms have not been proactive but have simply benefited from A's poor policies on capacity. Surprisingly, their contract completions exceed those of A for the best part of three years (figure 6).

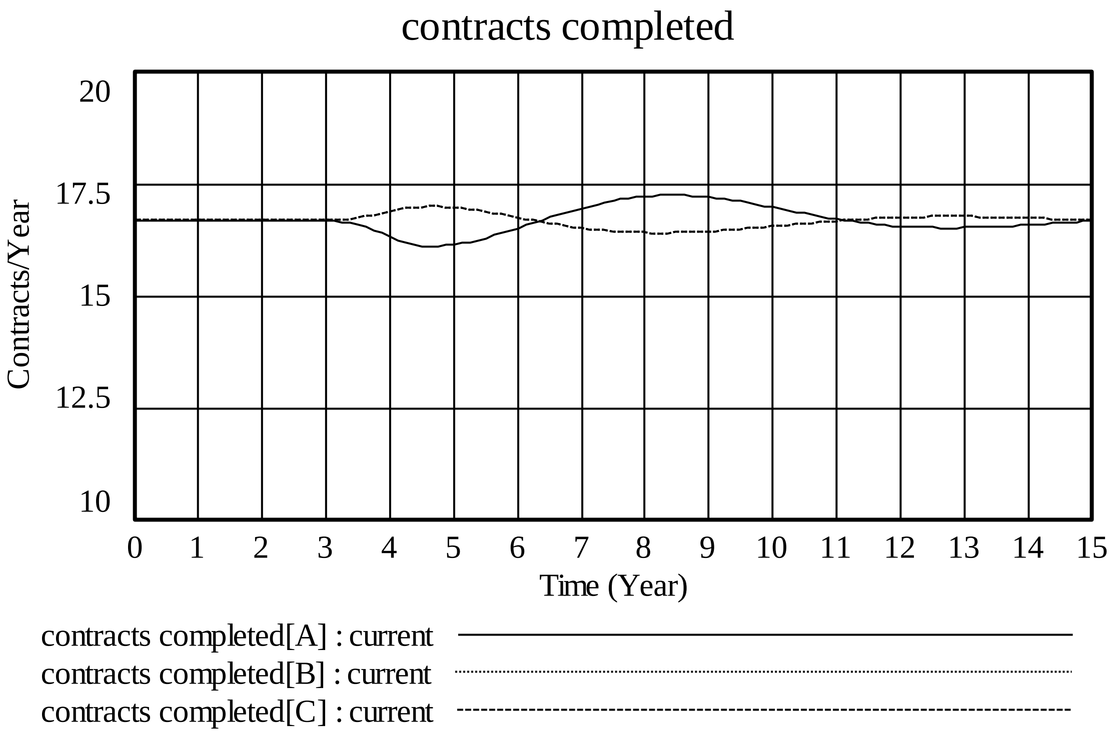

Figure 6: Reduced completions in years 3-6 by Firm A because of work-in-progress build up

CONCLUSIONS

Space prevents detailed discussion of further experiments which have been conducted with the existing model. For instance the strength of competitive behaviour (how avidly the firm pursues new contracts) has been shown to be a determinant of profitability. The more aggressive competitive behaviour produces the most severe oscillations in profits. A more measured approach produces oscillations which are much more attenuated. It is planned to assess the merits of frameworks as an approach to future contracting behaviour.

However, the over-riding conclusion is that 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.

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