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Some results from a system dynamics model of construction sector competitiveness

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ABSTRACT

Despite government-led good practice initiatives aimed to improve competitiveness in the U.K. construction sector, fluctuations in growth-driven demand, investment and constant regulatory revisions make it very difficult for an enterprise to plan strategically and remain competitive over a timescale exceeding 2–3 years. Research has been carried out to understand the historical evolution and changing face of the construction sector and the dynamic capabilities needed for an enterprise to secure a more sustainable competitive future. A dynamic model of a typical contracting firm has been created based on extensive knowledge capture arising from fieldwork in collaborating firms together with a detailed review of the literature. A construct called the competitive index is used to model contract allocation in a stylised market. The simulations presented enable contracting enterprises to reflect strategically with a view to remaining competitive over a much longer time horizon of between 15 and 20 years. The rehearsal of strategy through simulated scenarios helps to minimise unexpected behaviour and offers insights about how endogenous behaviour can shape the future of the enterprise. To date, work on construction competitiveness has been either of a static nature or set predominantly at the level of the project. This study offers a new perspective by providing a dynamic tool to analyse competitiveness. It creates a new paradigm to support enhanced construction sector performance.

1. Introduction

The primary aim of this research was to provide a fresh perspective on how enterprises operating within the U.K. construction sector can sustain their competitive advantage. Traditionally the sector plans for the short term [1] often looking no further forward than the next project and neglecting potential future trends and related changes in demand and culture. Likewise there is a need for contracting enterprises to broaden their sights in sensible preparation for such change by managing their internal structure and external influences to enable competitive manoeuvre appropriately [2].

The research collaboration splits the *competitiveness* focus in three ways. The project required an unusual variation of multiple research techniques forming a unique structure as outlined in the research plan to capture empirical data relevant to contracting enterprises[1] [3]. One set of researchers employed a case study method [4] and interview techniques [5] to capture the dynamic capabilities and historical evolution of construction enterprises [6]. Another group used workshop techniques to capture knowledge relevant to the potential futures of contracting enterprises [7,8]. Our focus was to ‘bring

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1 When referring to a sector regional contractor company, professional firm or organisation the word *enterprise* is used so to relate to any sector project specific business.

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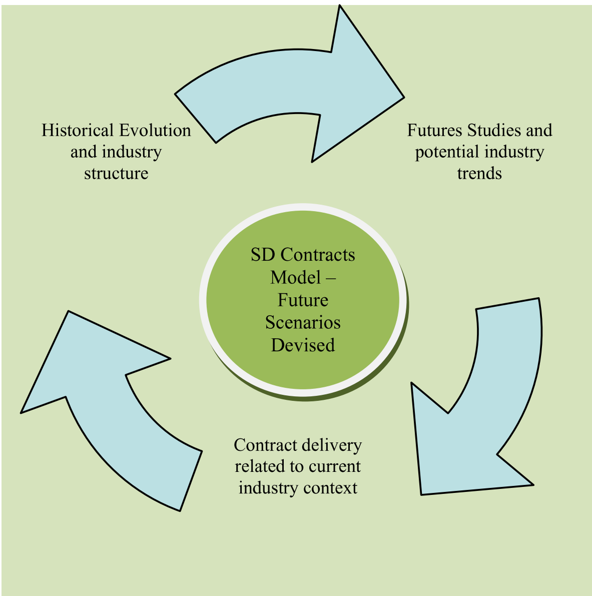

Fig. 1. The overall project process.

alive' the qualitative detail captured through interviews and workshops to allow an assessment of contract delivery in practice; this was achieved by means of a system dynamics model (SD). The various knowledge strands captured from the work-packages were synthesised in a model built to explore sustained competitiveness.

Competitive behaviour in the construction industry has been explored in the past [9,10] and some of this work has employed the system dynamics methodology [11–13]. The Ogunlana et al. [11] work is set at the level of the project; a similar level of aggregation is adopted by Katsanis [12]. The research by Kim and Reinschmidt [13] comes closest to our model although their work concentrates on the bidding process and does not employ a dynamic competitive index (as described below) which synthesises the various strands of competitiveness.

The SD methodology [14] was chosen to help understand the inter-related competitive forces at play in the industry because of its ability to handle interconnectivities arising from complicated feedback processes. Such interconnectivity is rife in the versatile construction sector of industry where many stakeholders operate at any one time both vertically and laterally throughout a typical construction project life cycle. The purpose of this study was to expose greater understanding of the dynamic inter-relationships between the differing factors which impinge upon competitiveness in a construction enterprise [15]. The outcome was the development of a model-based tool for thinking and an enhanced ability to support strategy for sustained competitiveness.

System Dynamics has been used to model economies, societies and environmental systems [16–18]. However, due to its ability to provide insight in complex, high-order and non-linear systems and to recognise that detached events are often mutually connected [19], it was considered appropriate for this application. The reasons for the choice are further explained in Dangerfield et al. [20].

2. Capturing the dynamic capabilities of the construction enterprise

There are many elements to the competitive strategy of a regional contracting enterprise, as indeed there exists facing any enterprise [21–23]. Seminal work by Porter [24] examined how planners expand to competitive actions to secure advantage over rivals, providing analytical techniques for understanding the competitive behaviour of such rivals. This supplied industry sectors with the five forces of competitiveness comprising endogenous and exogenous enablers: the competitive rivalry within an industry, the bargaining power of suppliers, bargaining power of customers, threat of new entrants and the threat of substitute products [25]. The overall process of the project is portrayed in Fig. 1.

Further to this Green et al. [26] discuss strategy and interconnected competitive influences, as reflected in Fig. 2. This enables a company to understand their sector structure to target positioning for greater competitive advantage leading to increased profits with concomitant reduced risk [27].

Initially a high level map of the contracts model was produced to portray the essential ingredients for a construction enterprise to operate: human resources, material supplies and finance (see Fig. 3). Here the political, economical, social, technological, legal and environmental (PESTLE) influences exogenous to the sector and those endogenous factors: finance, human resources, materials, assets, programme of works including late starts and over-runs were considered. These latter aspects have a considerable impact on an enterprise's reputation and cannot be omitted from a model intended to illuminate the factors contributing to sustained competitiveness. The feedback loop portrayed at the bottom of Fig. 3 is continuously

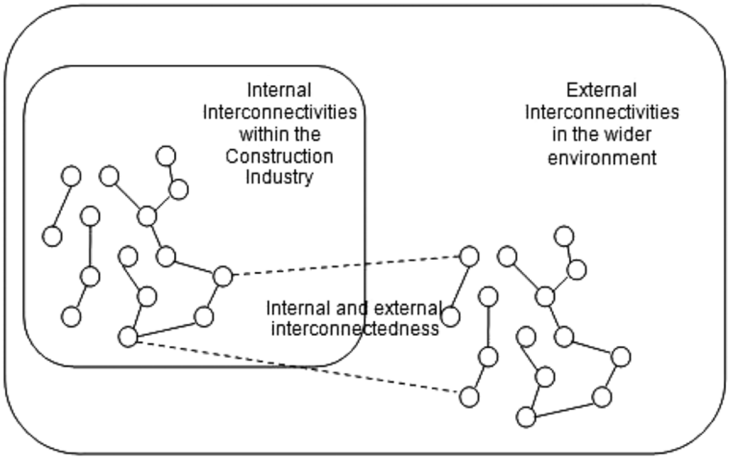

Fig. 2. Internal and external competitive interconnected influences [28].

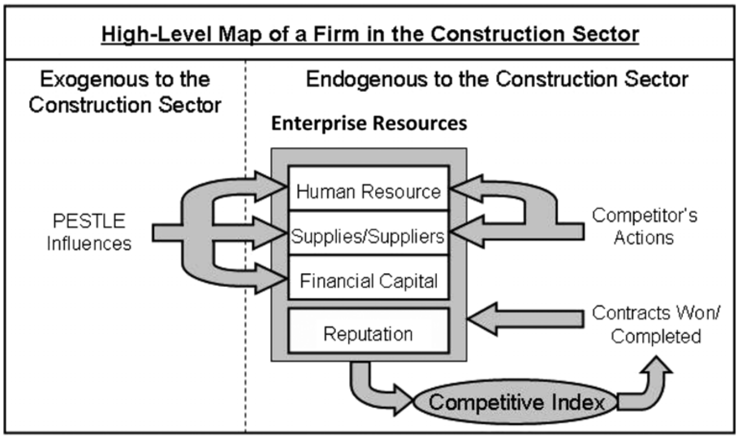

Fig. 3. A high level map of the contracts model [29].

live both in the real world and our model. Also, competitors' actions can impact on human resources (through, for instance, wage settlements) and supplies (high demand from one sector or country pushing up the price or availability of crucial commodities) and therefore need to be considered in scenario runs.

3. Knowledge capture for the contracts model

An element of this research was to establish qualitative data encompassing specific interconnectivities surrounding contract delivery [30,31] as enterprises need to respond to a constantly changing environment to sustain competitiveness [32]. An interview technique with successful contractors based in the North-West of England was used to capture knowledge from which effective 'knowledge strands' were developed for inclusion in the SD model. This further supplemented the findings derived from our collaborators' efforts. The specific focus was to devise various 'knowledge strands' related to competitiveness in practice.

A semi-structured questionnaire was created and released to a selection of sector actors based on their expertise and experience in different aspects within the construction sector so as to achieve a broad knowledge base spanning both the project life cycle and the supply chain. The questions were carefully devised to capture data relevant to all circumstances and aspects of competitiveness in contract delivery. The candidates included a registered social landlord (RSL), a manufacturer of off-site construction fabrications (modern methods of construction), a specialist sub-contracting heating engineer and a housing contractor for residential and shelter dwellings.

4. Detailed formulation of the model

The primary objective was to develop an integrated tool able to support strategy for sustained competitiveness. The SD methodology is similar to case study research in that both capture information from an actual case; however SD

Table 1
Knowledge strands included in the contracts model.

Contract delivery related to current industry context
Contractor selection and partnering supply chain
Winning work; workforce as a reputation-defining asset
Poor workmanship and construction defects
Payments and relationships
Compliance with environmental regulations and requirements
Risk of resource capacity constraints
Understanding the market

Table 2
Main parameter values in the contracts model.

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

takes the descriptive data further because the causal interconnectivities identified can be used to simulate dynamic behaviour. Essentially the method has the capability to understand how both the internal and external interconnected activities relate [33]. The empirical data captured from the research collaborators and our interviews enabled the model to be developed. A range of policy factors were included as shown in Table 1. The model was programmed using the VENSIM™ software.

The model was developed to portray possible future strategy considerations by construction sector enterprises. The various model variables interact through causative links and feedback loops. The model provides understanding of sector structure flows, delays, information and feedback which, once run as computer simulations, informs potential strategic futures. Model parameters were elicited during a series of interviews with senior management from a range of industry enterprises and the interview process described earlier. The main parameters are listed in Table 2.

5. The competitive index

A competitive index (CI) was developed so as to synthesise the effects of a number of factors which define the multi-dimensional perspective of competitiveness in the contracting industry. These included cash-flow, delays in completing and starting contracts, the number of sub-contracted workers and supplier relationships. Fig. 4 illustrates the detail of the competitive index (CI) for a single enterprise. For example, when delays are reduced litigation may be avoided thereby maintaining an organisation's reputation and improving its CI. The CI is effectively a dynamic key performance indicator (KPI) for construction competitiveness.

The references [34,35] in respect of the Chinese construction industry reveal that an index of this type is not a new idea. But whereas their (slightly different) index formulations are used on *ex post* construction industry data and in a static framework, ours is embedded in a dynamic model and so is continually being re-computed whilst simulated time is progressing as the simulation proceeds.

The weights (W_i) represent the weight accorded to the competitiveness factor (CFi) in that construction sector or market environment. These are held fixed in any one run and will reflect the appropriate weightings for any given sector. The weights must sum to 1.0.

The spoke lengths (CFi) represent the value of that competitiveness factor on a normalised scale 0–1, for a specific enterprise. These will vary dynamically as the simulation progresses.

For the purposes of illustration we model three enterprises (A–C) competing in one contracting sub sector. The CI expands those aspects defined in the high level map (Fig. 3). The model normalises the CI values, so that the highest possible CI will be 1.0, although >1 competing enterprise can secure such a value since the CI is computed for each competing enterprise separately. The delay in completing a contract can have a significant bearing on the competitive index variable. There is a non-linear relationship between contract completion time and the resultant penalty. The penalty will arise due to the enterprise breaching its capacity limit, causing delays in completing contracts. Any resulting drop in CI will give them a smaller share of the contracts on offer in the market.

The mathematics involved is briefly explained in Fig. 4. 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)

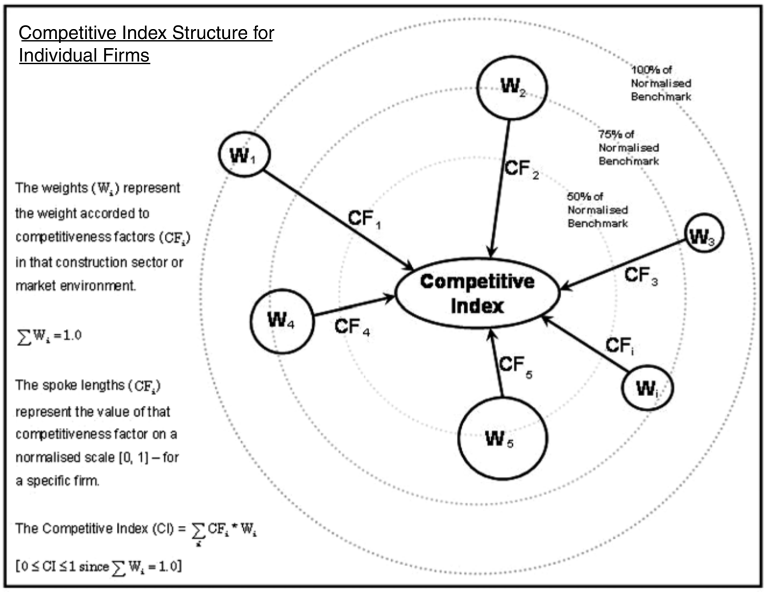

Fig. 4. Detail of the workings of the competitive index.
Source: Reproduced from Dangerfield et al. [20].

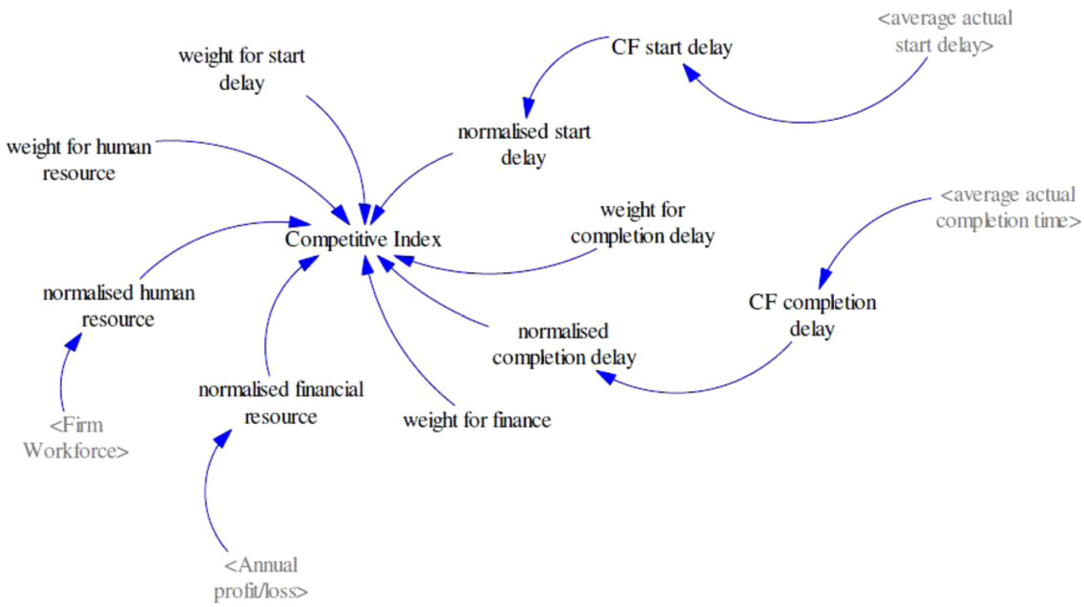

Fig. 5. Influences on the competitive index (variables in angled brackets represent those computed in another model sector).

of the three competing enterprise'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 et al. [35]. The approach they have adopted ensures that the full range of the scale is used. Thus, under their method, one enterprise will always score 0 and another 1.0 on any given competitive factor. On the other hand, the method we have adopted allows one to determine how far off the 'best' any given enterprise is for any given competitive factor. It should be understood that if each of the three enterprises has the same CI they will each receive an equal share of the contracts on offer in the market: one-third in this case. For further details see Dangerfield et al. [20].

The various competitive factors considered are depicted on the causal diagram in Fig. 5.

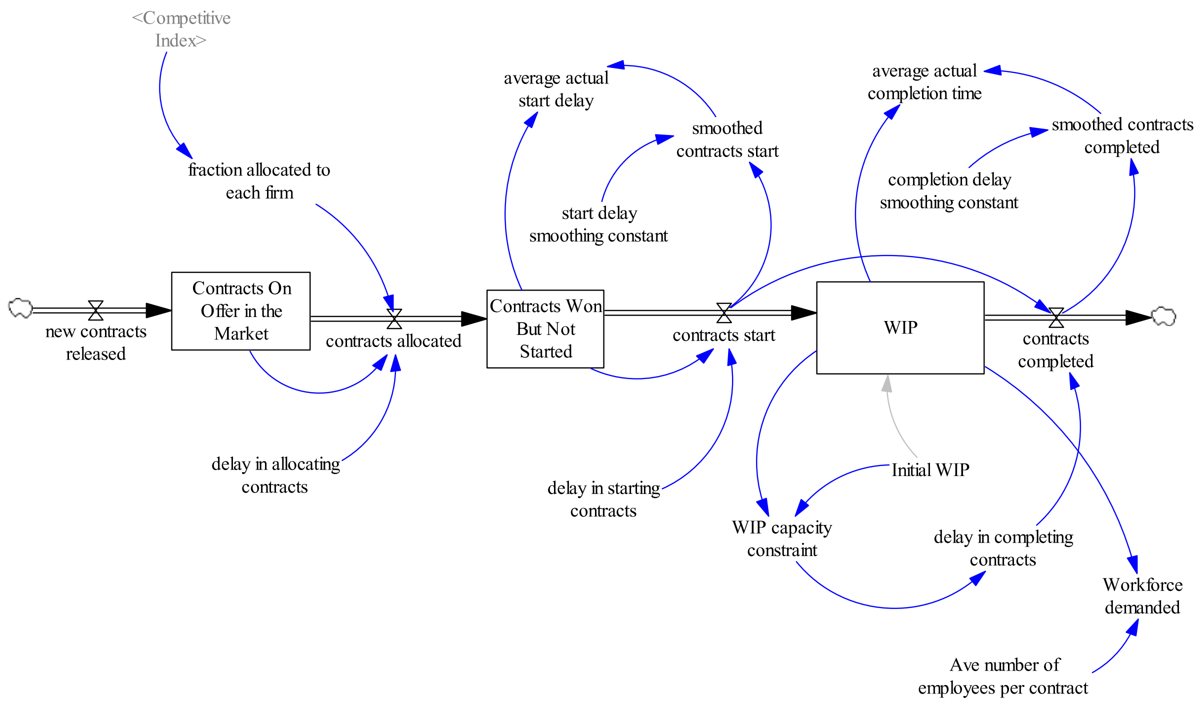

Fig. 6. Flow diagram of the contracts sector.

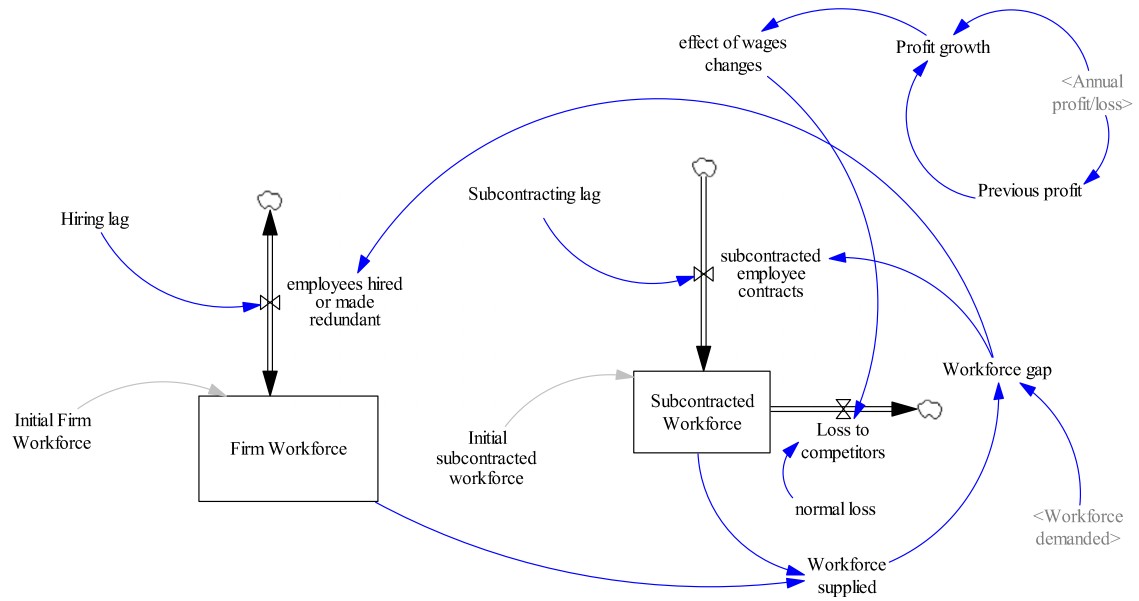

Fig. 7. View of the human resource sector of the model.

Fig. 6 shows the stock-flow structure dealing with contact achievement whilst Fig. 7 concerns human resource aspects and Fig. 8 the financial sector of the model. Successful bids are determined by the competitive index simultaneously considering contract completion, delays, human resource and finance variables. An increase in contracts allocated is associated with the reputational aspect of achieving programmes within timescales.

6. Model validation

The validation of an SD model is grounded in gaining confidence that the model is an adequate representation of the real-world system it seeks to emulate. In the case of a model formulated for the purpose of analysing a specific problem in an

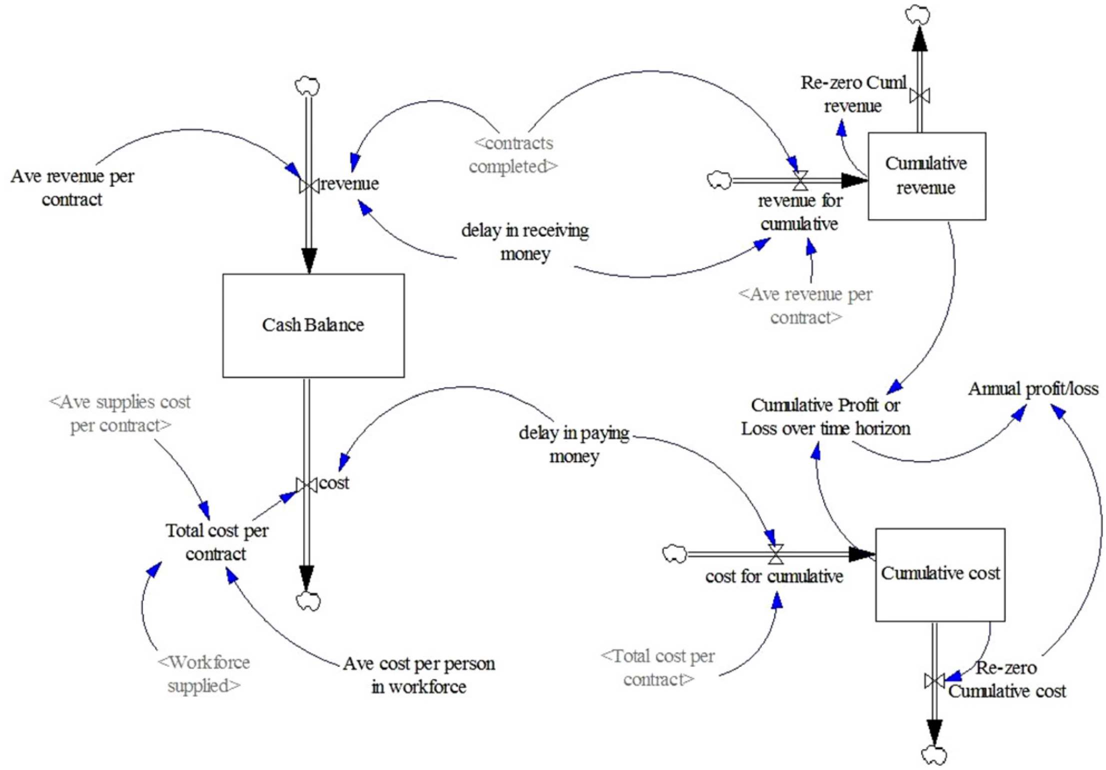

Fig. 8. View of the financial sector of the model.

organisation this process will equate to acquiring acceptance from a closely involved client set and, possibly, demonstrating that the base case behaviour qualitatively accords with known reported (past) data.

In this case the model is generic, although it could be parameterised to a specific contracting enterprise if necessary. Therefore the validation process is changed to exposing the model to a range of industry experts, inviting their comments and hopefully securing 'buy-in' to the model for providing a tool for thinking about industry competitiveness.

A group of leading sector based stakeholders were selected: one of the practitioners worked for a family-owned main contractor with a GBP100 million turnover. Another worked for a civil engineering contractor with a GBP40 million turnover. The third was an executive director for a major international contractor, again with a multi million pound turnover. Prior to the sessions (there was more than one) preparatory dialogue took place and a full brief was provided outlining the research aim, objectives and progress along with information of how the SD method is used to develop a model. This helped the delegates understand how the model worked and how the dynamics portrayed were influenced by the model structure and the parameter values.

Participants were asked to review the model and to identify any flaws or potential improvements. Discussion and critical appraisal captured missing elements that needed to be included in an amended model. Delegates found themselves thinking about future scenarios for the sector and the constituent enterprises. After surfacing their thoughts, delegates discussed potential revisions with the modelling team who subsequently adjusted the model appropriately.

7. Simulation output

The earlier paper by Dangerfield et al. [20] provides a detailed description of the model formulation and its use in the construction sector as well as potential outcomes and implications for sustained competitiveness. However, space afforded only a rudimentary consideration of the output. This section rectifies that shortcoming by reporting on some of the working SD model simulations which provide some interesting insights for construction sector competitiveness. Recall that an assumption was made of three competing sector enterprises. The simulations span a 15–20 year duration with a fixed time step of one-eighth of a year.

The model was designed to allow various simulations which would rehearse strategy and provide insight to possible future scenarios. The simulation runs were not intended as a means of reproducing a specific contracting enterprise's behaviour, but rather as a series of laboratory experiments that would heighten thinking about prospective strategies in the industry. Recall that this is an industry not especially known for thinking strategically and looking beyond the next project.

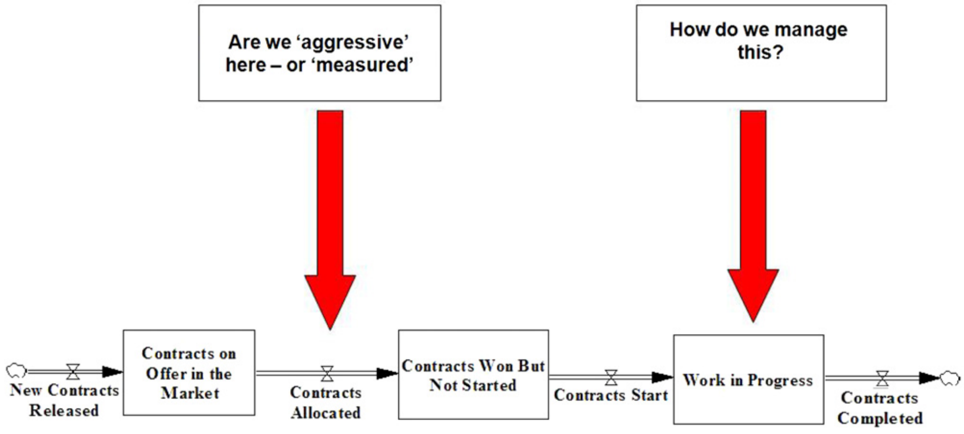

Fig. 9. Pressure points in the strategic analysis.

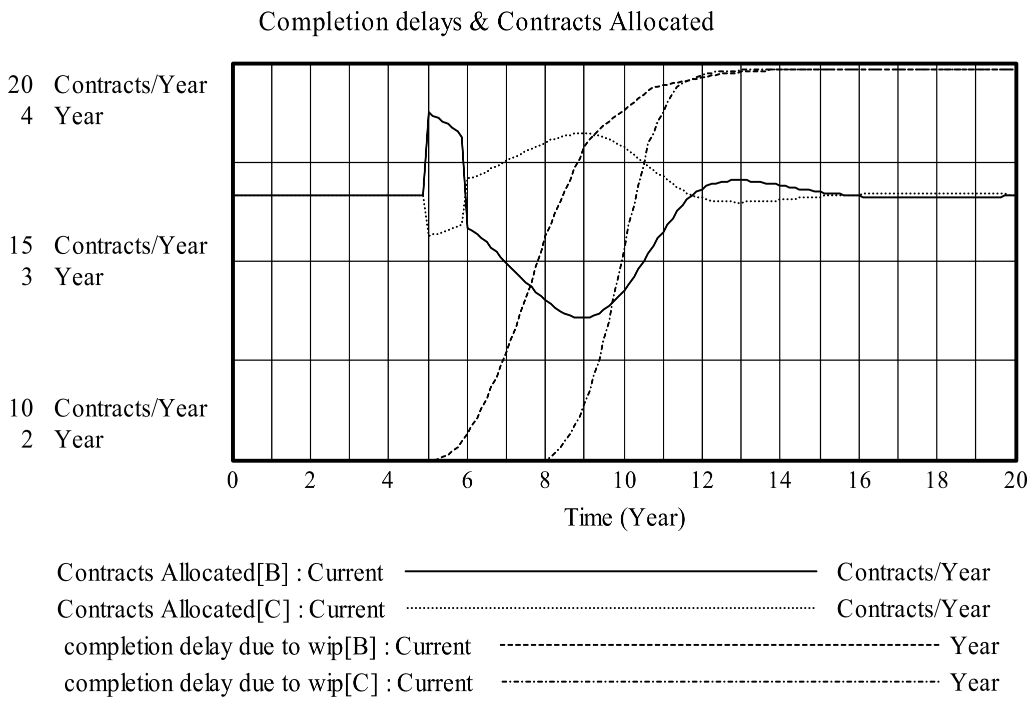

Fig. 10. Completion Delays and Contracts Allocated (NB. A's behaviour is identical with Enterprise 'C').

Possible focal points to consider are highlighted in Fig. 9. Under-performance in the management of work-in-progress will result in late contract completion. This is a major factor determining reputational aspects of a contracting enterprise for when the planned times for 'contract start' or 'contract completed' are not met their reputation is compromised affecting the chances of securing future contracts by virtue of the workings of the competitive index described above. A more aggressive ('hunter gatherer') approach to attempting to secure future contracts undermines the chances of timely starts and completions.

The simulation depicted in Fig. 10 shows a possible dynamic arising in this context. Within the three assumed competitors, Enterprise B is arbitrarily given a boost to competitiveness in year 5. This disturbance offers 'B' a competitive advantage over its rivals. Despite this benefit within a few years there are serious problems because their completion delays start to rise alarmingly (from 2 years to 3 on average by year 8). The growth of work-in-progress (usually accompanied by a spurt in re-work arising from excessive urgency to complete) puts significant pressure on their resources and their ability to win future contracts is compromised (See Fig. 11). Indeed, it is possible their management might refrain from bidding at all, given the pressures in handling current projects. We can conclude the management of resource capacity is crucial here.

Interestingly, we can see from Fig. 10 that enterprise 'C' ('A' is equivalent) did not actively introduce an innovative strategy to gain an advantage over their rivals, but rather they simply benefited from the consequence of enterprise 'B' taking on too

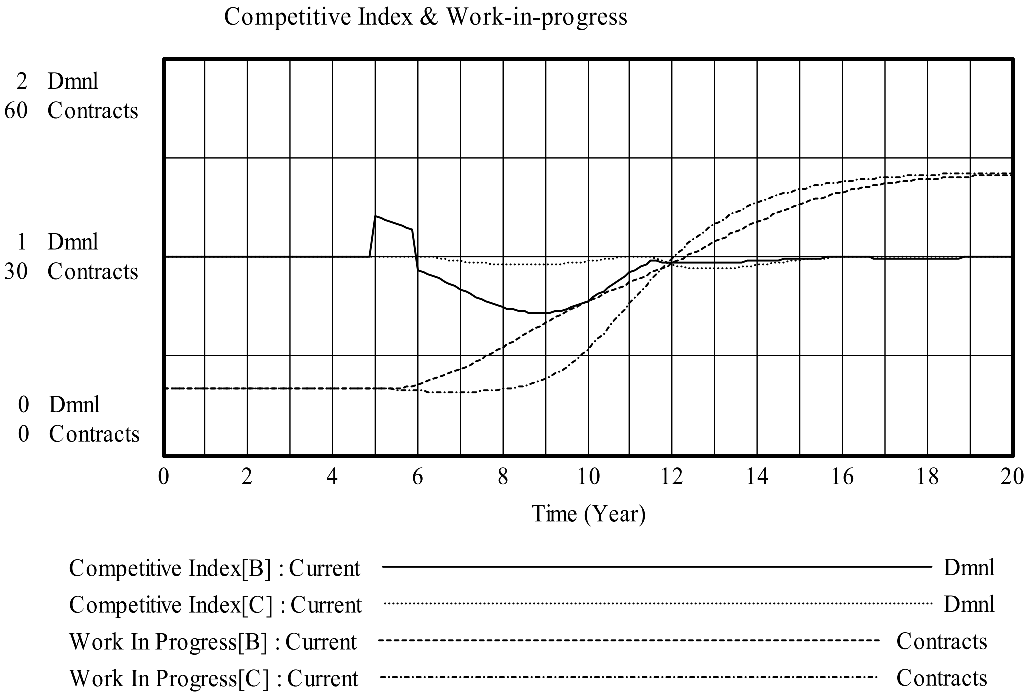

Fig. 11. B's Competitive Index declines associated with a growth of work-in-progress (NB. 'Dmnl' = dimensionless).

many contracts at the same time which led to their inability to sustain competitiveness. This corresponds with qualitative knowledge achieved from our interviews that some enterprises will tender for contracts even when they do not have the resources to deliver to programme. In practice part of a contracting enterprise's strategic plan may include drafting in extra resource through a great deal of sub-contracting, but with this option there is considerable risk attached.

The competition dynamics further unfold in that enterprise 'C' starts to gain from B's problems. It experiences a boost in contracts awarded which, in turn, puts pressure on its own resources. C's completion delays start to rise during years 8–10 and, in consequence, it too experiences a downturn in new contracts allocated in years 9–12. The message is that competing contracting enterprises need to consider not only the competitive (external) position, which can deliver benefits from little proactive effort, but their own internal resource management. Also it is worth remarking that an arbitrary disturbance in year 5 has created dynamics in the sector which only begin to settle in year 12.

A further experiment considered the financial repercussions from various styles of competitive behaviour (see Fig. 12 where the annual results from enterprise 'A' are shown arising from three styles of competitive behaviour). The graph illustrates conformity with the competition literature in that as aggressive competitive behaviour increases, so do the resources devoted to the bidding process. It should be noted that in adopting this style there is an associated risk of litigation through penalty allocations. In consequence, along with the dynamics portrayed in Figs. 10 and 11, the more aggressive style can result in larger swings in the profit and loss account. Shareholders may appreciate short-term gains but a more measured competitive approach can secure a more sustainable financial position.

A final graph relates the contract position with the financial one (Fig. 13). The graph shows that subsequent to enterprise B completing their contracts after their peak in new contract allocation, their profits take a dip due to the lack of contract starts. In general profit reported will lag the contracts situation by around 2 years. This could have consequences because the time when resources are most needed could coalesce with an inability to finance or procure the much-needed extra resources.

8. Discussion and conclusions

Detailed information capture shaped the research process here. Once knowledge elicitation had been completed it was used to structure the formulation of the contracting model described. It was quickly established that competitiveness had to be viewed as a multi-dimensional concept and there needed to be an artefact which could enumerate this concept: the competitive index was the result. Further details are provided in Dangerfield et al. [20].

It was established that there are many external and internal contract issues to consider in seeking a strategy for sustained competitiveness. For the contracting enterprise the main external drivers for change are in demand and sector culture. But the actions of rival competitors can affect the economic and financial climate as when, for instance, an established firm offers significant wage rises to skilled employees. Such action can produce contagion effects. Strategy is also moulded by

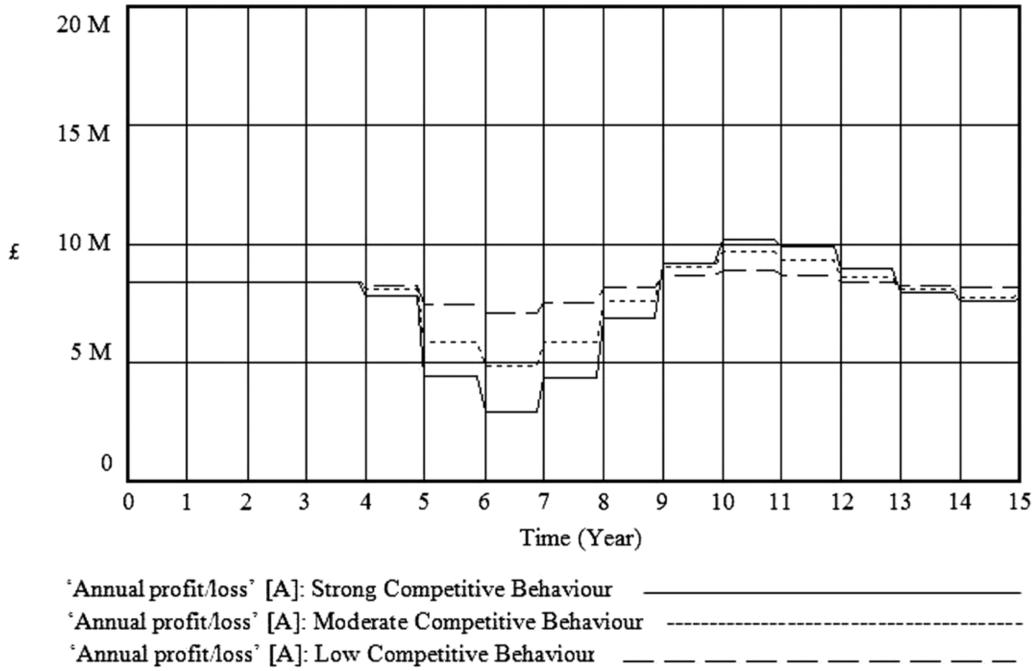

Fig. 12. Annual profit and loss arising from different styles of competitive behaviour.

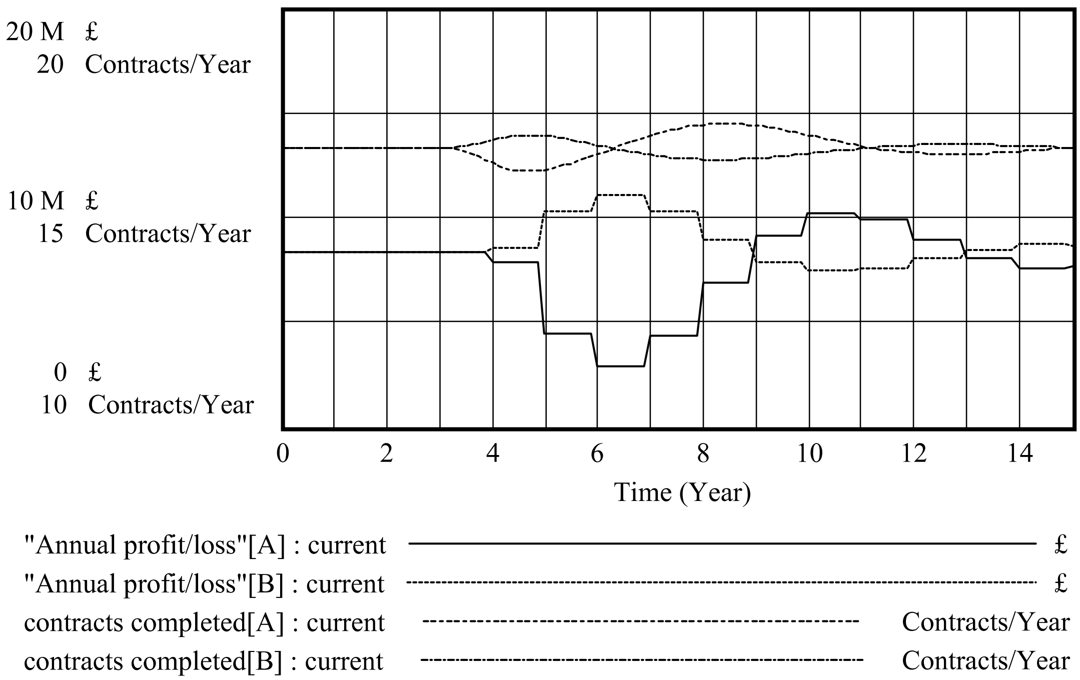

Fig. 13. Profits performance lags contract completions.

many internal influences. This includes the historical evolution of the enterprise and their traditional norms and practices. Construction firms are apt to operate in a conservative manner based on tried and trusted practices. Carrying this into the modern market place may not provide for a successful future. The ability to make alterations to suit the changing environment is what Green et al. [36] refer to as dynamic capabilities: the degree to which the enterprise is acceptable and adaptable to change. Our modelling suggests that contracting enterprises should continually revisit strategic influences; just when they are enjoying good returns and healthy business is the time when the seeds of future problems might be sown.

It is suggested that the behaviour of contracting enterprises should regularly embrace the rehearsal of potential scenarios to provide insight into future strategy for sustained competitiveness in the construction process. The model described above has enabled policy decisions and practices to be explored at the level of the enterprise to provide insight to strategic direction in both the short and long term. It has the ability to assist those involved in contract procurement by overcoming the associated complexities in strategic delivery of sector projects, whilst minimising unexpected behaviour and allowing a proactive dimension to strategic planning.

The interconnected complex elements that shape construction sector competitiveness were successfully modelled to provide what is really a strategic guide to assist those involved in contract procurement and execution. The model was formulated from the knowledge of all the influential factors in contract delivery that had been elicited from industry collaborators. It really is a tool for thinking; one that informs an enterprise of possible (but not assured) outcomes. It stands in sharp distinction to the traditional (static and cross-sectional) statistical assessment measures for competitiveness. The SD model then is not a tool to be used for predicting an enterprise's competitive future, rather it is one to help shape and design that future. It has the ability to engage industry participants with regard to possible future outcomes. This information can then inspire strategic planning for sustainability in the context of legal, political, economic, social, technological, environmental or structural issues.

With the creation of the competitive contracting model (and other exemplar models not reported here) it has been demonstrated that the system dynamics methodology is fit for purpose in the construction industry in this particular context. The methodology is beyond the proof of concept stage for this purpose. Moreover, as a contribution to knowledge, the research has satisfied the project's main aim: to provide a fresh perspective in the competitiveness research arena and to offer a new paradigm to improve construction sector performance.

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References

[1] J.R. Brightman, C. Eden, K. van der Heijden, D.A. Langford, The development of the construction alternative futures explorer, Automation in Construction 8 (1999) 613–623.
[2] C. Harty, C.I. Goodier, R. Soetanto, S.A. Austin, A.R.J. Dainty, A.D.F. Price, The futures of construction: a critical review of construction futures studies, Construction Management and Economics 25 (5) (2007) 477–493.
[3] C.I. Goodier, R. Soetanto, A.R.J. Dainty, G.D. Larsen, M. Quigley, Towards sustained competitiveness in UK construction: a multi-methodological approach, Proceedings of CIB World Building Congress: Construction for Development, 14–17 May 2007, Cape Town, 2007 pp. 915–927.
[4] R.K. Yin, Case Study Research: Design and Methods, Sage, Thousand Oaks, CA, 2002.
[5] R. Fellows, A. Liu, Research Methods for Construction, 2nd ed. Blackwell Science Ltd., 2003.
[6] S.D. Green, G.D. Larsen, C.C. Kao, Competitive strategy revisited: contested concepts and dynamic capabilities, Construction Management and Economics 26 (1) (2008) 63–78.
[7] R. Soetanto, C.I. Goodier, S.A. Austin, A.R.J. Dainty, A.D.F. Price, Scenario planning for construction companies. Presented at Construction Management and Economics 25th Anniversary Conference, 16–18 July 2007.
[8] C.I. Goodier, S.A. Austin, R. Soetanto, A.R.J. Dainty, Causal mapping and scenario building with multiple organisations, Futures 42 (3) (2010) 219–229.
[9] D. Drew, M. Skitmore, The effect of contract type and size on competitiveness in bidding, Construction Management and Economics 15 (5) (1997) 469–489.
[10] C.J. Katsanis, C.H. Davidson, Horizon 2020: how will North America build? International Journal of Architectural Management Practice and Research 9 (1995) 146–162.
[11] S.O. Ogunlana, H. Li, F.A. Sukhera, System dynamics approach to exploring performance enhancement in a construction organisation, Journal of Construction Engineering and Management 129 (5) (2003) 528–536.
[12] C.J. Katsanis, System dynamics modeling for a decision support system for assessing construction productivity, Proceedings of the 5th Construction Specialty Conference of the Canadian Society for Civil Engineering, Moncton, New Brunswick, Canada, 2003.
[13] J. Kim, K. Reinschmidt, A dynamic competition model for construction contractors, Construction Management and Economics 24 (2006) 955–965.
[14] J.W. Forrester, Industrial Dynamics, The M.I.T. Press, USA, 1961 (now available from Pegasus Communications, Waltham, MA).
[15] D.J. Teece, G. Pisano, A. Shuen, Dynamic capabilities and strategic management, Strategic Management Journal 18 (7) (1997) 509–533.
[16] J.D. Sterman, Business Dynamics: Systems Thinking and Modelling for a Complex World, McGraw-Hill, New York, 2000.
[17] D.H. Meadows, D.L. Meadows, J. Randers, Beyond the Limits, Chelsea Green Publications, 1992.
[18] D.H. Meadows, J. Randers, D.L. Meadows, Limits to Growth: The 30-Year Update, Chelsea Green Publications, 2004.
[19] P.M. Senge, The Fifth Discipline, Doubleday, New York, 1990.
[20] B. Dangerfield, S. Green, S. Austin, Understanding construction competitiveness: the contribution of system dynamics, Construction Innovation: Information, Process, Management 10 (4) (2010) 408–420.
[21] R. Feurer, K. Chaharbaghi, Defining Competitiveness: a holistic approach, Management Decision 32 (2) (1994) 49–58.
[22] C. Eden, F. Ackermann, Making Strategy: The Journey of Strategic Management, Sage Publications Ltd., London, 1998.
[23] J. Barney, Firm resources and sustained competitive advantage, Journal of Management 17 (1) (1991) 99–120.
[24] M.E. Porter, Competitive Strategy—Techniques for Analysing Industries and Competitors, Free Press, New York, 1980.
[25] M.E. Porter, The Five Competitive Forces That Shape Strategy, Harvard Business Review 86 (1) (2008) 78–93 (updated version of 1979 article).
[26] S.D. Green, C.F. Harty, A.A. Elmualim, G.D. Larsen, C.C. Kao, On the discourse of construction competitiveness, Building Research and Information 36 (5) (2008) 426–435.
[27] M. Betts, G. Ofori, Strategic planning for competitive advantage in construction, Construction Management and Economics 10 (6) (1992) 511–532.

[28] A. Fleming, G. Aouad, P. Barrett, B. Dangerfield, M. Kagioglou, P. McDermott, A review of system dynamics and its potential application to the UK construction sector, Proceedings of CIB W65 Conference, Delft, The Netherlands, 2006.
[29] B. Dangerfield, M. Quigley, J. Kearney, A dynamic policy model to manage temporal performance amongst contracting firms in a competitive situation, In: Proceedings of the International Conference of the System Dynamics Society, Athens, 2008.
[30] M. Quigley, R. Kearney, System dynamics modelling of competing UK construction firms, in: Proceedings of the CIB (W92 Procurement Systems), Conference: Interdisciplinarity in Built Environment Procurement, Hunter Valley, Australia, 2007.
[31] N. Gilkinson, A. Fleming, G. Aouad, The identification of contributory drivers for competitive contract delivery, The SCRI International Research Symposium, The Lowry, Salford Quays, Greater Manchester, UK, Jan 27–28, 2009.
[32] P.M. Hillebrandt, J. Cannon, P. Lansley, The Construction Company in and out of Recession, Macmillan, London, 1995.
[33] D. Runge, Towards Understanding System Dynamics, D-Memo, System Dynamics Group, MIT, 1977.
[34] W.S. Lu, A system for assessing and communicating contractors' competitiveness, Ph.D. Thesis, Department of Building and Real Estate, Hong Kong Polytechnic 2006 (unpublished).
[35] K. Sha, J. Yang, R. Song, Competitiveness assessment system for China's construction industry, Building Research and Information 36 (1) (2008) 97–109.
[36] S.D. Green, C.C. Kao, G.D. Larsen, Contextualist research; iterating between methods while following an empirically grounded approach, Journal of Construction Engineering and Management 136 (2010) 117.